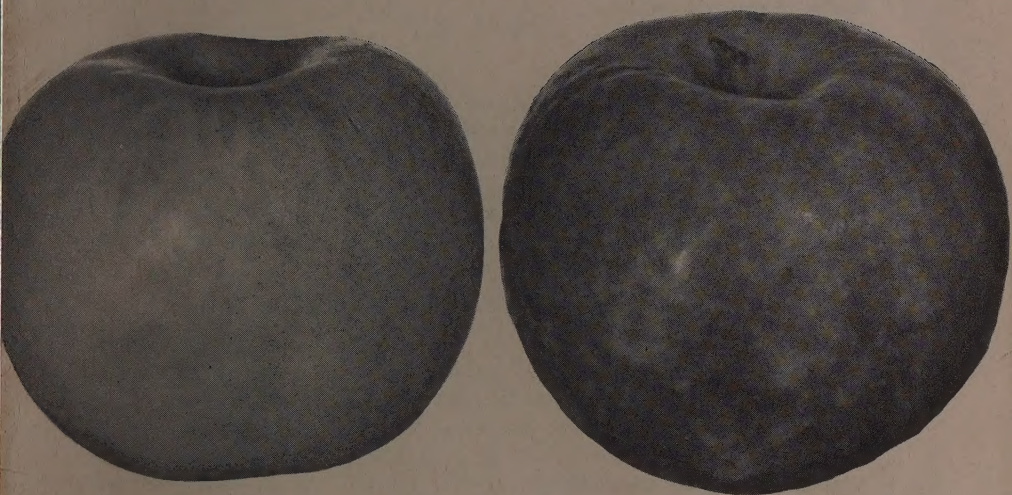
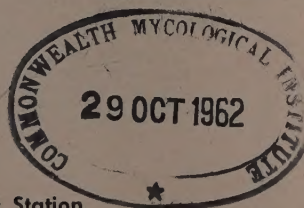
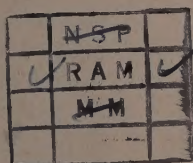




Methods of Scald Control on the Apple

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Methods of Scald Control on the Apple

R. M. Smock*

Scald is a nonparasitic storage disease of the apple that may cause great financial losses to fruit growers. The apple skin becomes brown and the fruit is unsalable on the fresh-fruit market (see cover). In its late stages the disorder affects the flesh so deeply that the fruit cannot be peeled properly for processing.

Review of the Scald Problem

Tissues affected

Scald discoloration of Granny Smith apples was due to a progressive browning of the contents of hypodermal cells (4). The epidermis was not affected unless scald was severe. In severely scalded fruits the affected cells of the hypodermis collapsed in a radial direction so that the brown areas became sunken. A study of the Ontario variety revealed that in the early stages of scald development the cells around the lenticels were not affected but that in the late stages they were discolored (41).

Cause of scald

Martin (57) and Fidler (27) have reviewed the historical development of research on this disease. Despite all the research of the past 40 years, the exact cause of scald is still not known.

The work of Brooks, Cooley, and Fisher (8, 9, 10, 11, 12, and 13) led to the view that fruit volatiles cause the trouble and that their removal will control it. It is no longer agreed among researchers that volatiles do directly or indirectly cause scald. It seems fairly clear that ethylene evolved by apples has no direct connection with scald (34, 44, and 66). A number of workers have shown that relatively high levels of esters induce artificial scald

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on apples (9, 10, 44, 53, 68, and 69). Among the most potent artificial-scald-producing esters is hexyl acetate (35 and 44). Workers in Japan (65 and 66) reported that acetaldehyde accumulations might cause scald on the apple, but this idea has not been generally accepted. Other workers have shown that, in the storage room, concentrations of volatiles approaching naturally occurring levels did not increase scald (60 and 119).

Another theory about the cause of scald is that the causal substance may be less volatile than those so far identified (44). It has also been suggested that the causative condition may be the accumulation of precursors of odorous volatiles (34). Another proposal (24) is that one of the causal factors is a substance (factor y) of low volatility at storage temperatures and another nonvolatile substance (factor x). Still another idea is that scald is caused by an accumulation of toxic substances beneath the cuticle, since cuticle removal lessened the scald (97 and 100). One worker thought that the oil fraction of the cuticle had no relation to scald but that other cuticle fractions might have (41).

Scald is known to reduce the respiration rate of apple skin cells, but this is probably an indication of the onset of death (101). It has been shown that there is also an increase in catecholase activity in brown-colored apple skins, but this finding does not throw much light on the cause of the disease (68). No difference has been found in the polyphenol oxidase activity of fruit that does not scald and fruit that does (80). Ascorbic acid losses (15 and 80) and other organic acid changes (65) did not seem related to scald development. In another study (7), however, it was proposed that high ascorbic acid in relation to dehydroascorbic acid resulted in resistance to scald.

The clearest statement on a possible cause of scald comes from Buchloh (15). He believes that the first steps in the production of scald are initiated by an enzyme occurring in a combined form in the chloroplast fraction of the hypodermis and epidermis: "It is conceivable that ferricytochrome C oxidizes phenol or polyphenol, the resulting oxidation products then secondarily inhibit respiration of the affected epidermis."

Induction period for scald

Scald is probably induced fairly early in the storage season even though it may not actually appear until much later. Apples that are apparently scald-free when removed from storage may show scald when warmed for several days at 70° F. These apples obviously had scald but the symptoms were not evident at low storage temperatures.

The induction period has been studied by applying or removing oiled-paper wraps after varying periods of storage. Usually it has been found that the induction period is apparently the first 4 or 5 weeks of storage (12). For Granny Smith, an apple that has a long storage life, it was the first 12 weeks of storage (71). In a study with Newton Wonder, the greatest amount of scald appeared on apples unwrapped during the third

to sixth week of storage (47). Bramley Seedling apples have been warmed to 60° F. for 5 days at 2-week intervals during storage (102). There was a progressive reduction in scald and a lessening of severity with successive intervals of time from the second to the twelfth week. An unexplained result in this study was the fact that there was no scald when the fruit was warmed at 16 to 20 weeks. When mineral oil was applied at different periods of storage, the January application seemed to give some scald control for Cortland apples (98). However, it is possible that in this study the oil application merely delayed the appearance of the scald.

The induction period on Delicious and Winesap apples has been studied by applying diphenylamine (DPA) or washing it off after varying periods of storage (95a). The induction period for Delicious began in less than 7 days; for Winesap it did not begin until after 42 days of storage at 31° F.

Orchard factors affecting susceptibility

Climate. It is a well-established fact that scald susceptibility varies from season to season. Apples from trees with late heavy rainfall or irrigation were reported to be more scald-susceptible (36). Martin (57) has pointed out that scald is worse on the mainland of Australia, where the growing seasons are warm than in Tasmania where the growing seasons are cool. In an experiment with controlled temperatures around the limbs of McIntosh trees the last 3 weeks of the growing season, high night temperatures resulted in 100 percent scald and low night temperatures in only 2 percent scald (126). In another study, a fair correlation was found between high temperatures during the last 6 weeks of the growing season and scald (109). In England, a stronger correlation was found between scald and high evaporation in relation to the amount of rainfall (26). This finding of the effect of hot, dry weather during the last 6 weeks of the growing season corroborates an 1897 observation (45). It was recorded that "scald is very bad when the falls are warm and dry." In a 4-year experiment with Stayman it was found that scald was held to a minimum if picking was delayed until 150 hours with a temperature below 50° F. had accumulated after September 15 (63). Where limbs of R. I. Greening were shaded with white cheesecloth during the latter part of the growing season there was usually less scald (105).

Orchard nutrition. While it has been stated that high nitrogen fertilization results in increased scald (33 and 120), often no consistent effects have been found (19, 42, 105, and 113). Two reports on the Cortland variety showed less scald with high nitrogen fertilization (22 and 92).

It has been reported that high rates of potash fertilization resulted in more scald (50). With potash deficiency, however, maturation is hastened on the tree and more mature fruit is generally less susceptible to scald.

Fruit size. It is generally agreed that large apples are more susceptible to scald than small ones (27, 57, and 92). Yet in years of high susceptibility, the author has observed 100 percent scald on small apples.

Defoliation. Removal of leaves from individual branches in the latter part of the growing season has reduced scald in limited trials (105).

Spray program. In 2 studies, Fermate used as a fungicide resulted in slightly more scald (18 and 79). In one study sulfur used as a fungicide resulted in the least scald (18). In other studies no effect of fungicide or insecticide was found on scald susceptibility (72 and 116).

Growers commonly state that scald is more severe than it was 20 to 30 years ago. One theory accounts this difference to the present-day use of "mild fungicides." There is little proof for this theory but it is one that deserves further evaluation. As stated above (18), one study showed less scald when sulfur was used as a fungicide. The author has noticed that when apples are russeted, there is less scald. This observation tends to confirm the observation that the presence of healthy cuticle tends to aggravate scald (97 and 100).

Fruit maturity. It is generally agreed that, under regular cold storage conditions, apples picked in an immature condition tend to scald the worst (11, 16, 17, 61, 105, 121, and 127). Tests with Granny Smith apples in Australia showed a sharp break in susceptibility in relation to picking date (122). Susceptibility was high before a certain picking date and much lower after that date. This observation may be related to Merritt's (63), which states that after a sufficient number of hours below 50° F. on the tree, susceptibility is greatly reduced.

There are exceptions to this generalization of the effect of picking date. McIntosh apples in controlled-atmosphere storage (CA) tend to scald worse if picked in an overmature condition (64). Overmature Golden Delicious placed in polyethylene box liners tend to scald worse than immature ones (38).

Post-harvest treatments influencing scald

Delayed storage. It might be assumed that when apples are going into regular storage, a delay period to ripen the fruit somewhat would lessen scald. In some studies this delay has decreased scald (11 and 43), whereas in others it has increased it (70 and 73). Delayed storage is certainly not a reasonable approach to solving the scald problem (105).

Oil and wax treatments. Certain oils and waxes when applied to apples either before or after harvest may reduce scald (13, 43, 98, 99, and 105). These treatments have not always given good control and there is danger of increasing internal fruit disorders, such as carbon dioxide injury.

Oiled paper. The first really effective method of controlling scald was introduced by Brooks, Cooley, and Fisher (12). It involved wrapping the fruits in oiled paper wraps (18% by weight of pure, odorless, white mineral oil) or in using ½ pound of shreds of oiled paper per bushel of fruit.

Box liners. Sealed box liners that permit a rather rapid oxygen drop within the package reduce scald (37, 38, 91, 110, and 129). Unsealed liners that do not affect the oxygen level within the package have generally

increased the scald on apples (38, 90, and 110). One report with Belle de Boskoop apples showed no increase of scald with unsealed box liners (125).

Chemical inhibitors. A dip of 500 p.p.m. of alpha-naphthalene acetic acid in lanolin paste was reported to reduce scald (94). This treatment never received commercial adoption because it was not effective enough. A Dutch patent covers the use of Chloramin T (sodium-p-tolulene sulfon chloramine) to prevent scald (21). This material was somewhat effective in English studies (25). The method involves some danger of fruit injury from the free chlorine and is not completely effective.

In 1955 it was reported that diphenylamine would reduce scald (108). Since that time, numerous confirmatory studies have been made (30, 35, 38, 39, 57, 58, 62, 76, 77, 78, 88, 110, 113, 114, 115, and 117). Occasional injuries have been reported with Rome Beauty and Delicious (30 and 39). Just how diphenylamine (DPA) controls scald is not known. Although it is a cytochrome oxidase inhibitor (1) as well as an inhibitor of carotene synthesis in micro-organisms (32, 93, and 124), Yatsu found that DPA did not inhibit cytochrome oxidase activity appreciably except in senescence of the fruit (130). He found that DPA was an uncoupler of oxidative phosphorylation and that it inhibited the succinoxidase system of apple fruit mitochondria. He found that DPA-treated apple skins were slightly higher in titrable acidity in the early storage season. There were higher than normal concentrations of asparagine, glutamic acid, and alanine in DPA-treated fruit skins. It is not known just how these findings relate to the scald-controlling ability of DPA.

In 1957 it was reported that Santoquin¹ or Ethoxyquin¹ (6 ethoxy-1, 2, -dihydro-2, 2, 4-trimethyl quinoline) had scald-reducing properties (110). This material is now sold as Stop Scald¹ and was cleared by the Food and Drug Administration in 1960 with a tolerance of 3 p.p.m. residue. In various trials it has given poor to excellent results (59, 77, 95A, and 96). It was found that deposits and coverage were best with dip treatments (59).

Studies in Holland showed that 10,000 p.p.m. of sym-dimethyldiphenyl urea had scald-reducing properties (114). Among other chemicals reported to have scald-reducing powers were ascorbic, gallic, tannic acids, (77) and impure hexane (44).

Gamma radiation. Cortland apples given 2500 to 30,000 reps (cobalt source) of gamma radiation did not show less scald than untreated fruits (111). In another study with McIntosh apples, 85,000 reps of gamma radiation reduced scald somewhat, but softening of the fruit was increased (85).

Storage factors influencing scald

Temperature. Early studies showed that scald was worse at higher storage temperatures up to 60° F., but that there was no scald at 86° F. (8). Minimal scald development at low storage temperatures has been commonly reported since that time (36 and 46). Tindale (122) pointed out that in

¹ Patented by Monsanto Chemical Co., St. Louis, Missouri.

scald-temperature studies, the apples should be stored until they have equal degrees of ripeness before scald counts are made. He concluded that scald was a low-temperature disorder of Granny Smith apples. One report with Cortlands has shown that scald was worse at 32° than at 40° F. (113).

Temperature modification during storage sometimes has reduced scald. For example, warming the apples to 59° F. every 2 weeks for 24 hours controlled scald (48). In another study with Bramley Seedling apples, scald was reduced by warming the fruits to 60° F. at 2-week intervals for 5 days (102). With the Bohnapfel in Switzerland, scald was reduced by heating the apples to 104° F. for 10 minutes before storage (117). Melville and Hardisty (61) were the first to report that storage for the first month at 40° F. and then at the lower temperature of 32° F. would reduce the scald on Granny Smiths stored in oiled paper wraps. Both success (40) and failure (72) with this method when used on Granny Smith have been reported in New Zealand. In one study with Cortlands, modified-temperature storage resulted in less scald (113). Temperature modification must inevitably result in somewhat riper fruit.

Ventilation. Brooks, Cooley, and Fisher (8) reported that good aeration would reduce scald. Ventilation was presumed to flush away the "toxic materials" that caused scald. In one study with R. I. Greening apples, as many as 40 air displacements an hour did not entirely control scald, although they did reduce it (105).

Intervariety effects. Kidd and West (51) were the first to find that one variety of apples can influence the scald on another variety, when stored together. In several small-scale trials, the vapors of McIntosh increased the scald on R. I. Greening apples (105). The results were not striking, however. There have been other reports of inter-variety scald influences (75 and 118).

Air purification. On the assumption that scald is caused by volatiles, various methods of volatile removal have been studied. Air purification with activated coconut shell carbon has been reported to reduce but not control scald (5, 82, 105, 106, and 107). Other investigations showed no scald reduction with this method (24, 28, 29, and 31). One study showed a 50 per cent scald reduction when brominated activated carbon was used as the air purifying agent (24 and 25). Air purification with alkaline potassium permanganate was shown to reduce scald (52), but a later report from the same experiment station showed no control (128).

In Europe, air purification with water ("luftwäsche") has been studied in relation to scald control. One study showed some reduction in scald (14) but another found only questionable scald reduction (23).

It is evident that air purification is still a controversial method of scald control.

Ozone. Ozone used at relatively high concentrations (1 to 3 p.p.m.) has reduced scald (8, 95, and 104). This treatment can result in fruit injury and it may make the skin of the fruit sticky.

Controlled-atmosphere storage. Early in the history of controlled-atmosphere (CA) storage it was reported that this type of storage increased scald (49). The atmosphere used usually involved 11 to 16 percent oxygen. It is now believed that scald is worse in restricted, ventilated atmospheres in this oxygen range. If the oxygen level is dropped rapidly and held at 2 to 3 percent, there is usually less scald (6, 38, 80, 103, 105, and 129).

Generally speaking, prestorage treatments with high levels of carbon dioxide (25 to 50 percent) or storage with 2 to 5 percent CO₂ and reduced oxygen levels have reduced scald (2, 9, 80, 86, and 87). There is danger of injury with relatively high levels of carbon dioxide. Work in Australia has shown that for certain varieties, scald is increased with carbon dioxide levels elevated much above normal (56).

Relative humidity. Research workers seem agreed that high relative humidities (90 to 100 percent) increase scald (9, 27, 44, and 105). The only contradiction comes from research workers in New Zealand who found that dry conditions increased scald on Sturmer Pippin apples (54). The relative humidity must be left at 85 to 90 percent or higher to prevent undue weight loss from the fruit, so control of the relative humidity is not a practical approach to the scald problem.

Methods Used in the Study

Most of the apples used in this study were obtained from the Cornell University Orchards. In 1959 and 1960 the spray treatments were applied to Rome Beauty trees in a Wayne County, New York, orchard. The Rome Beauties used for other methods of treatment in 1960 were from this same orchard. In 1956, Rome Beauty apples were obtained from 7 different orchards around the state for DPA dip treatments.

Except for fruit maturity studies, the apples were picked from 1 to 2 weeks before normal picking time to try to accentuate the scald problem. For regular storage the apples were stored in air at 32°, 36°, and 38° F. until January to April. Unless otherwise specified, the fruits stored in controlled-atmosphere storage (CA) were held in 5 percent carbon dioxide and 3 percent oxygen at 38° F. until March or April. All apples were held for 7 days after storage at 70° F. before scald counts were made.

Scald was evaluated as "slight", "severe", and "total". "Slight" meant that the apples had just a few streaks of scald whereas "severe" meant that the fruits had up to 100 percent of the surface covered with scald. Only "severe" and "total" scald are recorded in the tabular data. The "slight" can be determined by subtracting "severe" from "total".

Through 1958 the diphenylamine used was "refined flake" DPA, but in 1959 and 1960 a highly refined grade was used. Formulations are indicated in the tabular data. Through 1959 practically all formulations of DPA involved dissolving the DPA in isopropyl alcohol (110). To the emulsion was added 0.025 percent Tween 20 or Triton X 100. Various amounts of these

wetting agents were experimented with. In several experiments, concentrations as low as 0.006 percent were sufficient as a wetting agent but it was felt in large-scale trials that concentrations of 0.025 percent should be used. The emulsions were vigorously agitated before being used. The first dry wettable formulations were tried in 1959 and were used almost universally in 1960. They were made by commercial concerns and their exact composition was not known. They are referred to in tables as D. W. ("dry wettable").

Through 1958 pure "Ethoxyquin" or "Santoquin" was used. This material is 6-ethoxy-1, 2-dihydro-2, 2, 4, trimethylquinoline. In 1959 and 1960 both the pure material and the emulsified form of this material (sold as Stop Scald) was used. Use of the pure material is indicated in the table as a "100% formulation". It was used with isopropyl alcohol and wetting agents in the same manner as diphenylamine. Use of the emulsifiable material is specified in the tables according to the amount of active ingredient used, thus: "47 percent" or "70 percent". This material is referred to as Stop Scald in the tables.

The concentrations of all materials used are indicated in the tables. The figures refer to the concentration of active ingredients.

Climatological data were collected at an official weather station about $\frac{1}{4}$ mile from the Cornell orchards and at the same elevation. Average temperatures were the average of maximum and minimum readings at 60 inches from ground level. Evaporation was measured in inches from a standard evaporimeter with a pan that was 4' x 4' x 10" deep.

Fruit firmness was determined with a Magness-Taylor pressure tester on 20 to 80 apples from each treatment. Respiration measurements were made with a Beckman Instrument Co. G 2 oxygen analyzer.

Relation of Climate During Growing Season to Scald

It is well known that scald susceptibility varies from season to season, hence correlations with various climatic factors were attempted.

The severity of scald was judged on the basis of the scald intensity on each variety in all the experiments conducted in any one year. For example, if 5 experiments were conducted with McIntosh in a single year, the over-all intensity of scald in all experiments was evaluated. The scald indices given in figures 1 and 2 have the following values: 1=very slight, 2=slight, 3=moderate, 4=severe, and 5=very severe. The procedure used in this study is open to criticism. Fruit of exactly the same maturity was not necessarily picked and evaluated for all years. The fruit did not come from the same trees each year.

Figure 1 shows the correlation between average temperatures the last 6 weeks of the growing season and scald intensity for McIntosh for 18 years. The "r" value of .49 was significant but not highly significant. The data for

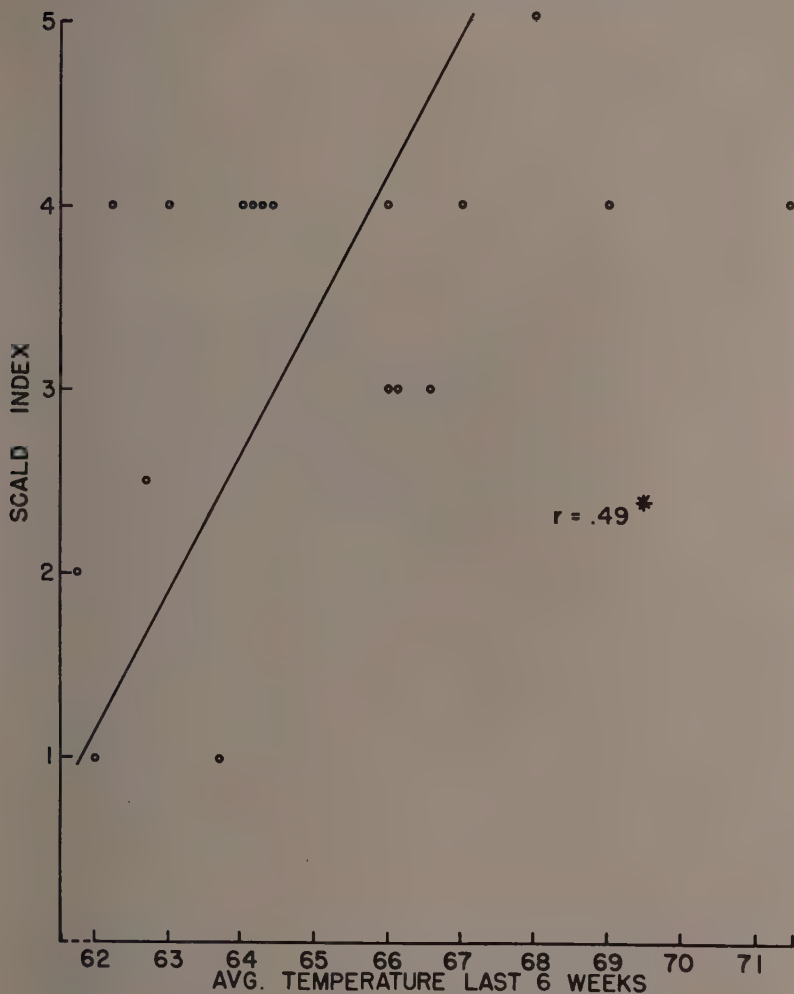


Figure 1. Relationship of scald and average temperature during last 6 weeks of growing season for 18 years with McIntosh apples.

R. I. Greening, covering 16 years, are not presented but the "r" value was .35, which was not quite significant.

A possible negative correlation between scald intensity and rainfall minus evaporation as suggested by Fidler (26) was also studied. Figure 2 shows the results for McIntosh. For the 17-year period the "r" value of $-.58$ was

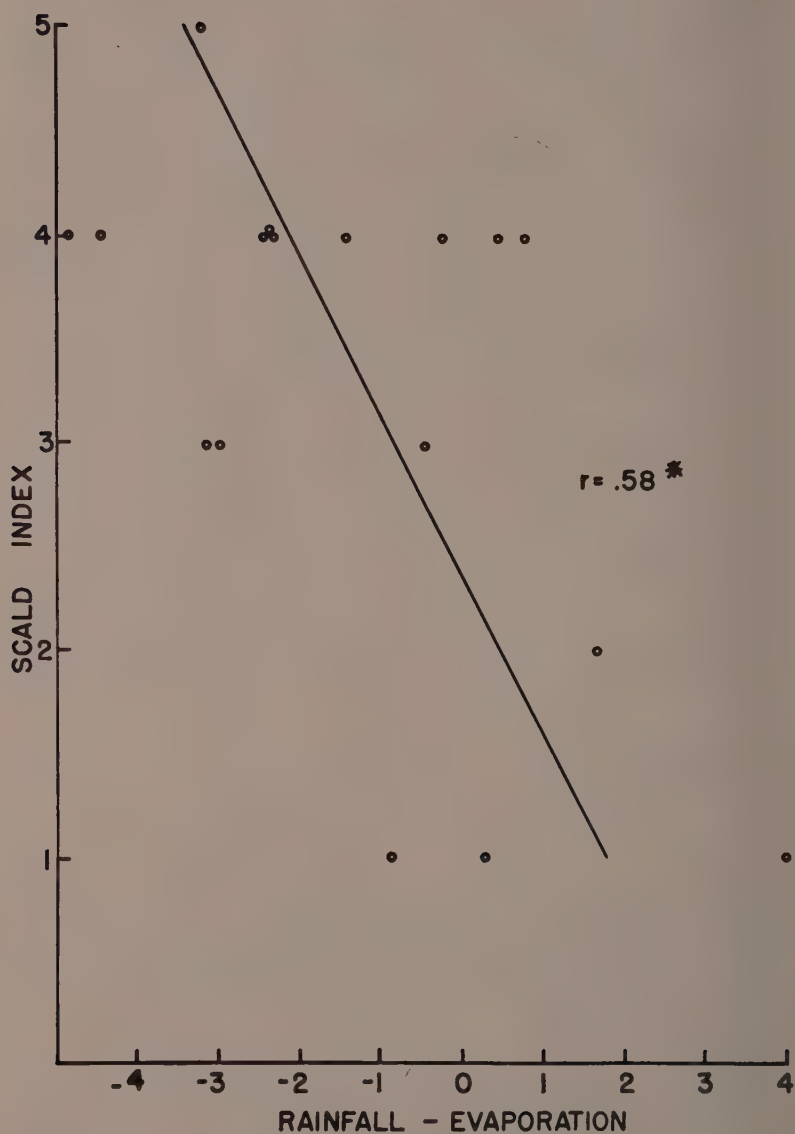


Figure 2. Relationship of "rainfall minus evaporation" and scald during last 6 weeks of growing season for 17 years with McIntosh apples.

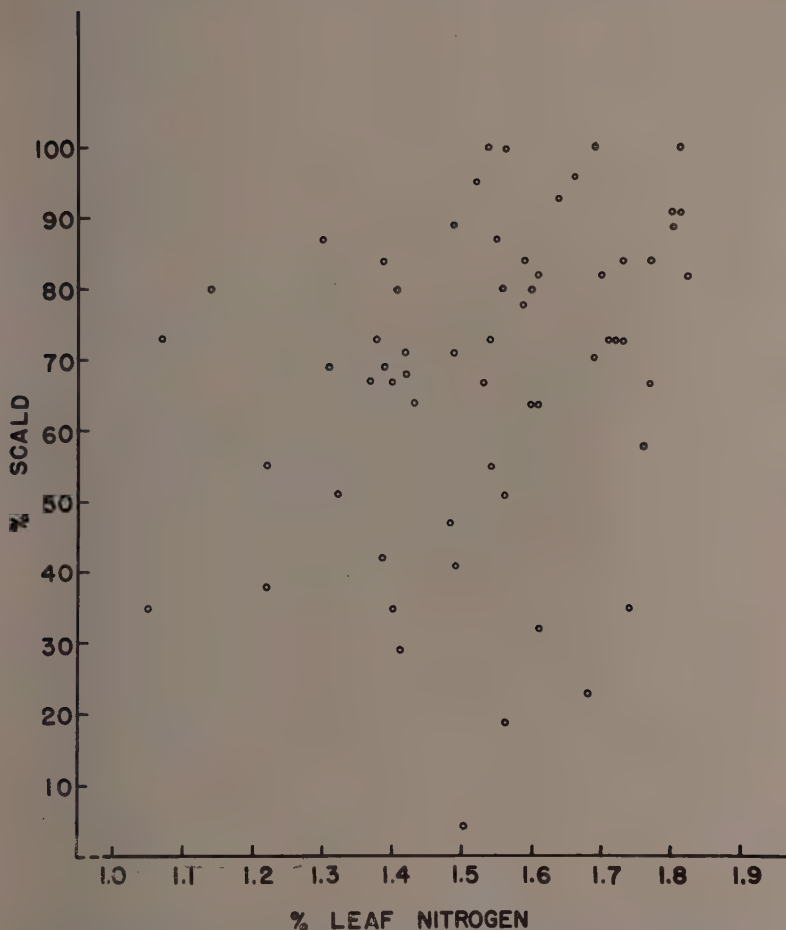


Figure 3. Scatter diagram of relation of scald to leaf nitrogen in a Hudson Valley McIntosh orchard in 1958. Each circle represents 1 tree.

significant but not highly significant (-0.59 required). This correlation was better for McIntosh than average temperatures with scald. The correlation for R. I. Greening for 17 years was only -0.01 , which was not significant. Why there was this difference in varieties is not clear. However, one of the complicating factors with the Greening is the fact that it is subject to russetting in some years.

Although the rainfall–evaporation relationship with scald on McIntosh was the best studied, it would seem that a critical factor may still have been overlooked in these climatic studies.

Effect of Tree Nutrition on Scald

This portion of the general study was done in cooperation with Dr. E. G. Fisher.

One-bushel samples were collected from each tree from which leaf samples had been taken for nitrogen analyses in July. Four Hudson Valley orchards were used in this study. One orchard was studied for 4 years, one for 2 years and two for 1 year only. A typical scatter diagram for one of these orchards is shown in figure 3. No relationship between leaf nitrogen in July and scald incidence in storage was seen in any of these comparisons for McIntosh. Cortland was studied for only 1 year in the Cornell orchard. In this instance there was a suggestion of less scald with higher nitrogen levels in the leaves. The “r” value noted in figure 4 was significant, but not highly so. In this experiment, half of the Cortland trees were treated with 3 pounds of ammonium nitrate and the other half untreated for 20 years. In 1958, the nitrated trees showed 41 percent total scald and the untreated trees showed 64 percent scald. R. I. Greening was studied for 1 year only in the Cornell orchards. There was no correlation between leaf nitrogen and scald incidence. It is concluded that, with the exception of Cortland, leaf nitrogen level had no apparent effect on scald incidence in this study.

A study was made of a possible correlation between leaf potassium and magnesium (sampled in early September) with scald of McIntosh. Four Hudson Valley orchards were studied for 1 year and 1 orchard for 2 years. There was no apparent correlation of leaf potassium and magnesium levels with scald.

Fruit Maturity

Regular storage

Two-bushel lots of R. I. Greening and Cortland apples were picked at 4 to 6 different dates about 1 week apart during the normal harvesting period for 7 years. These apples were stored at 38° F. The results were similar to those published earlier on 7 years' work (105) and are not given here. In general, as the apples became more mature on the tree they were less susceptible to scald. In more than one-half of the instances in the 14 years' data there was a sharp break in susceptibility in the late pickings. This has been reported by Tindale (122).

Controlled-atmosphere storage

Two-bushel lots of McIntosh were picked at different dates and stored in 5 percent carbon dioxide and 3 percent oxygen at 38° F. for 3 storage sea-

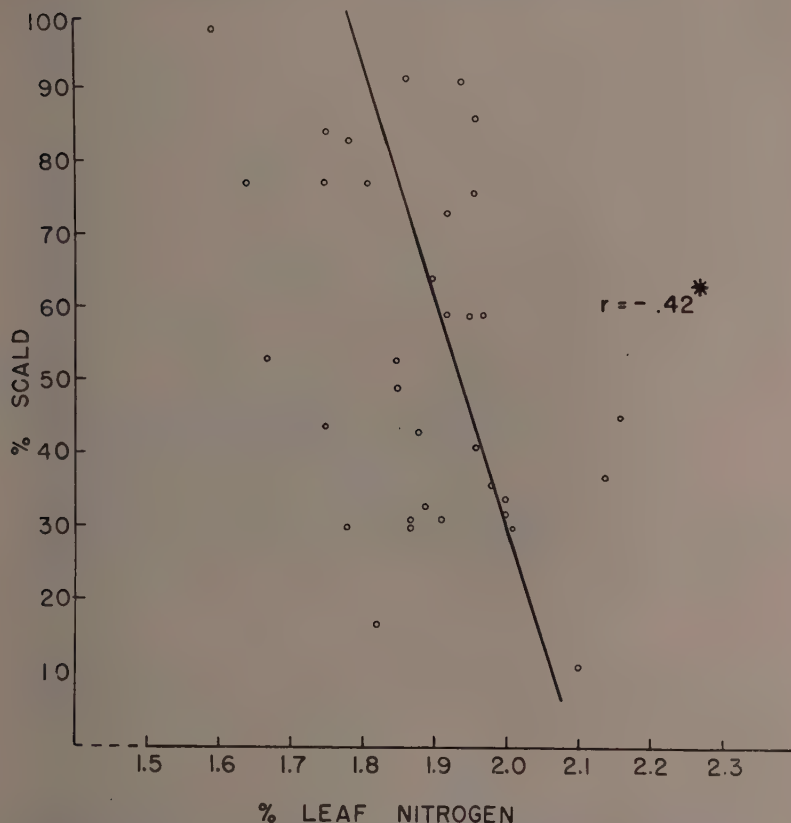


Figure 4. Relationship of scald on Cortland apples and leaf nitrogen content in 1958. Each circle represents 1 tree.

sons. The results in figure 5 show that late pickings were more susceptible to scald. This confirms the finding on delayed storage, which showed that mature fruits were more susceptible to scald. In 1960, McIntosh apples picked at different dates and stored in 32° F. air had less scald as the picking date was delayed. Yet the 1960 data for the same dates in figure 5 for controlled-atmosphere McIntosh show more scald as the picking date was delayed. It is not known why there is this difference in the relationship of type of storage to maturity. It may be another type of scald ("senescent"), but a 2000-p.p.m. diphenylamine dip controlled the scald in regular storage as well as in CA storage, regardless of picking date or delay. Whether this

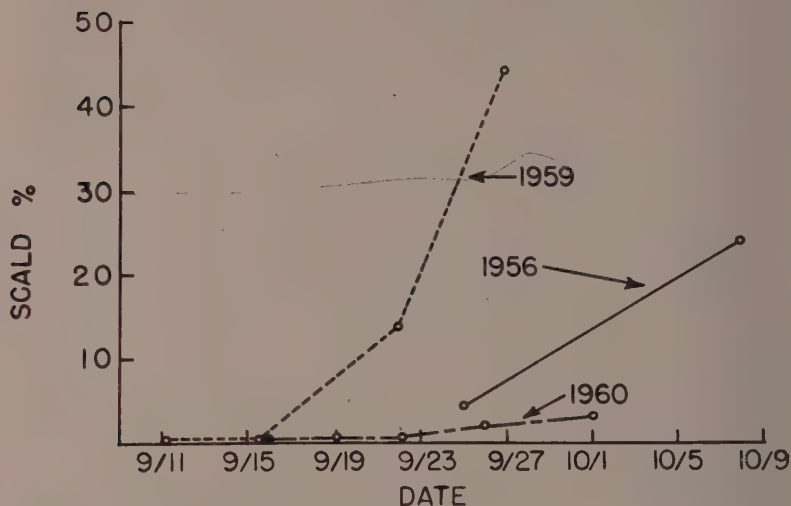


Figure 5. Scald on McIntosh apples stored in 5 percent carbon dioxide and 3 percent oxygen at 38° F., as influenced by harvest date.

principle applies to other varieties is not known, but 2 years' evidence suggests that it may not be true for Cortlands.

Delayed Storage

Regular storage

Apples were stored in air storage at 32° F. after 0-, 24-, 48-, and 72-hour delay periods at 70° F. The experiments were made for 2 years with Cortland and R.I. Greening and for 3 years with McIntosh. The data are not presented because they only confirm a previous report (105). Delayed storage had no consistent effect on scald.

Controlled-atmosphere storage

Two-bushel lots of McIntosh were delayed for 0, 24, and 72 hours at 70° F. before storage in 5 percent carbon dioxide and 3 percent oxygen at 38° F. Figure 6 shows the results over a period of 5 years. In 1 year no scald developed on any lot but in the other 4 years it is clear that delay increased the scald and resulted in softer fruit. Similar experiments were conducted with Cortlands for 2 years in CA storage. Delay did not significantly increase or decrease scald.

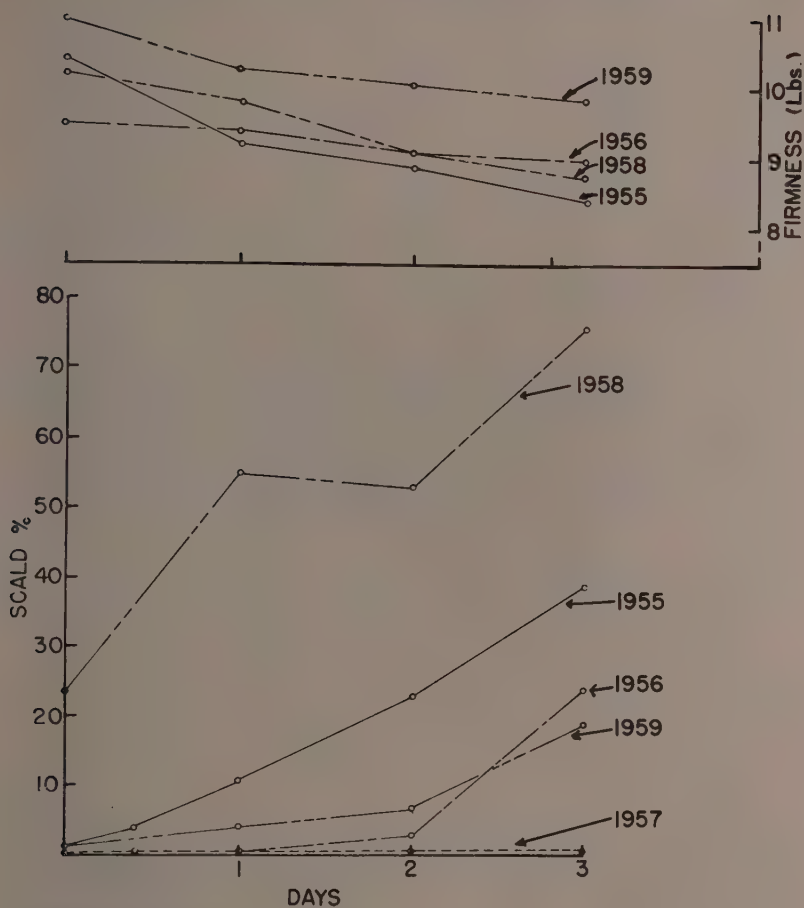


Figure 6. Effect of delayed storage for 1, 2, or 3 days on firmness (above) and scald (below) in CA storage of McIntosh apples.

Scald-Induction Period

An attempt was made to determine when the scald was induced by applying diphenylamine at different dates in storage. In each treatment were 2-bushel lots of fruit, stored in air at 32° F. The apples were treated with a 1000- or 2000-p.p.m. DPA dip at intervals (starting with the first day) of storage.

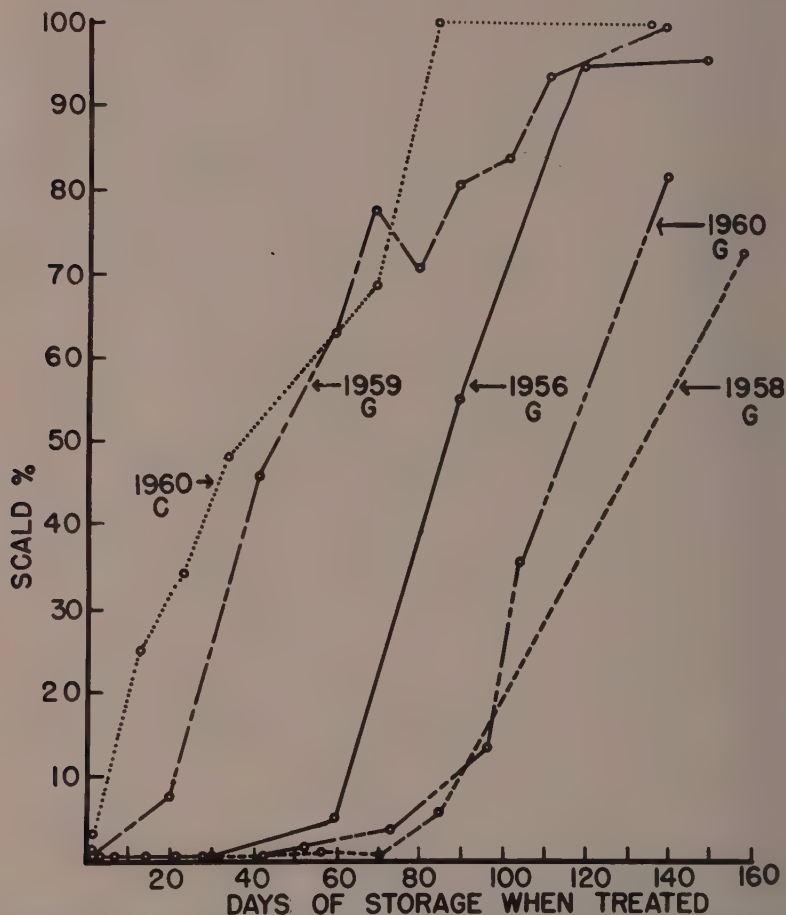


Figure 7. Scald on apples stored in air at 32° F. and with 2000 p.p.m. of diphenylamine. G=R. I. Greening, C=Cortland.

R. I. Greening results over a 4-year period are shown in figure 7. With the exception of 1959-1960, the scald was controlled if the application was made within the first 30 to 40 days of storage. In 1959-1960, there was some scald on the apples treated after 20 days of storage. This was a severe scald year.

In a 1-year trial with Cortland (figure 7), the induction period seemed to be earlier than that for Greening in the same year. Baldwin apples in a 1-year trial (1960), showed 30 percent scald when a 2000-p.p.m. DPA treat-

ment was made after 11 days of storage, and the scald increased with delay in treatment. By the 60th day there was 86 percent scald.

Predicting Scald Intensity

An attempt was made to predict the intensity of scald that might occur in any given year. It was found that all varieties tested (except Wealthy) would scald if held in an unsealed, 150-gauge polyethylene box liner for 4 to 6 weeks after harvest at 70° F. In setting up storage experiments to be held at 32° or 38° F., 1-bushel samples were also held in the poly liners at 70° F. The cold-storage samples were held for 4 to 5 months and those held at 70° F. for 4 to 6 weeks. It was found that a holding period of 6 weeks was better than one of 4.

The results are shown in table 1. It was apparent that the scald occurring in the liners at 70° F. was usually less than that occurring in cold storage. Furthermore, chemical treatments controlled the scald of apples stored in liners at 70° F. more effectively than of those held in cold storage. This method should serve as a rough prediction procedure, although it tended to underestimate the scald that developed in storage. The method was least useful with Wealthy apples.

Table 1. Scald in polyethylene liners at 70° F. versus scald in unlined boxes at 32° F.

Year	Variety	Total scald	
		Liner at 70° F.	No liner at 32° F.
Percent			
1959.....	R. I. Greening	83	98
1959.....	R. I. Greening	87	96
1960.....	R. I. Greening	45	94
1960.....	R. I. Greening	0	0
1960.....	R. I. Greening	0	25
1960.....	R. I. Greening	0	0
1959.....	McIntosh	82	88
1960.....	McIntosh	18	81
1957.....	Cortland	90	100
1957.....	Cortland	0	6
1957.....	Cortland	0	1
1957.....	Cortland	42	90
1957.....	Cortland	27	77
1957.....	Cortland	82	92
1957.....	Cortland	0	0
1959.....	Cortland	66	100
1959.....	Cortland	63	88
1959.....	Cortland	0	2
1959.....	Cortland	0	1
1959.....	Cortland	0	5
1959.....	Cortland	0	0
1959.....	Cortland	0	0
1959.....	Cortland	0	0
1959.....	Cortland	0	0
Average.....	(All varieties)	28	43

Varietal Response to Scald Inhibitors

Many chemicals were tested for their ability to control scald, and the two most promising were diphenylamine (DPA) and Stop Scald (Santoquin). Hence the majority of the experimental tests were made with these two materials. More than 100 separate experiments involving these materials were conducted throughout the 7-year period 1954-1960. The data are too voluminous to present as separate experiments, so the results are presented in 2 ways. The results for several varieties are presented for 1960-61 within the text. All other data are presented in summary tables.

Wealthy

It will be noted in table 2 that at approximately the same concentrations, DPA was superior to Stop Scald in scald control. Tree spraying gave the poorest scald control of the methods employed. Spraying open crates of fruit at the rate of 1 quart per box gave poor control also. With this variety, the materials did not seem to flow to the bottom (unexposed) sides of the fruit. Spraying the fruit as it went over a roller sorter gave fair but not good scald

Table 2. Scald control methods and results for Wealthy apples 1960-1961

Material	Formulation	Concentration	Method	Day picked after tree spraying	Trees	Fruit	Scald		Remarks
							Severe	Total	
	Percent	p.p.m.			Number	Percent			
Control ....	.....	.....	.....	.....	5	1,519	86	97	
Stop Scald	70	2,700	tree spray	0	5	802	17	57	
Stop Scald	70	3,600	tree spray	0	5	590	10	46	
DPA.....	42 D.W.	2,000	tree spray	0	5	512	8	31	
DPA.....	42 D.W.	3,000	tree spray	0	5	676	1	3	
Stop Scald	70	1,800	dip	.....	.....	999	1	6	
Stop Scald	70	2,700	dip	.....	.....	474	1	5	
Stop Scald	80	1,800	dip	.....	.....	532	0	2	
Stop Scald	80	2,700	dip	.....	.....	548	0	1	
DPA.....	42 D.W.	2,000	dip	.....	.....	522	1	2	
DPA.....	42 D.W.	3,000	dip	.....	.....	561	0	2	injury on bottom fruit
Stop Scald	70	1,800	crate spray	.....	.....	540	55	90	
Stop Scald	70	2,700	crate spray	.....	.....	519	30	65	
Stop Scald	70	3,600	crate spray	.....	.....	601	8	40	
Stop Scald	80	1,800	crate spray	.....	.....	513	21	58	
Stop Scald	80	2,700	crate spray	.....	.....	557	5	24	
Stop Scald	80	3,600	crate spray	.....	.....	674	4	17	
DPA.....	42 D.W.	2,000	crate spray	.....	.....	353	20	38	
DPA.....	42 D.W.	3,000	crate spray	.....	.....	346	1	10	injury on bottom fruit
Stop Scald	70	1,800	spray rollers	.....	.....	516	11	44	excessive stain
Stop Scald	70	2,700	spray rollers	.....	.....	501	7	33	excessive stain
Stop Scald	70	3,600	spray rollers	.....	.....	488	2	16	excessive stain
Stop Scald	80	1,800	spray rollers	.....	.....	496	2	11	excessive stain
Stop Scald	80	2,700	spray rollers	.....	.....	500	3	17	excessive stain
Stop Scald	80	3,600	spray rollers	.....	.....	339	0	4	excessive stain
DPA.....	42 D.W.	2,000	spray rollers	.....	.....	328	6	24	
DPA.....	42 D.W.	3,000	spray rollers	.....	.....	352	0	1	

control. There was considerable black stain on the fruits treated in this fashion with Stop Scald. This apparently resulted from applying the treatment outdoors. Exposure to sunshine seemed to accelerate the discoloration. Staining was not a problem with the other methods of application, although there was a little stain on the fruits sprayed on the tree. The higher concentrations of each material resulted in better scald control.

R. I. Greening

Diphenylamine (DPA) gave better scald control than Stop Scald at approximately equal concentrations. (See table 3.) Tree sprays gave the poorest scald control with both materials. It should be noted that as the interval between spraying and picking increased the scald was worse with both ma-

Table 3. Scald control methods and results for R. I. Greening apples 1960-1961

Material	Formulation	Concentration	Method	Day picked after tree spraying	Trees	Fruit	Scald		Remarks
							Severe	Total	
Control	Percent	p.p.m.		0		Number	Percent		
Control				0	8	1,375	23	91	
Stop Scald	70	2,700	tree spray	0	4	496	1	24	stain
Stop Scald	70	2,700	tree spray	2	4	411	2	44	stain
Stop Scald	70	2,700	tree spray	4	4	124	14	74	stain
DPA	42 D.W.	3,000	tree spray	0	4	532	0	0	
DPA	42 D.W.	3,000	tree spray	2	4	474	1	14	
DPA	42 D.W.	3,000	tree spray	4	4	133	1	17	
Stop Scald	70	1,800	dip			519	0	0	
Stop Scald	80	1,800	dip			482	0	0	
Stop Scald	70	2,700	dip			606	0	0	
DPA	42 D.W.	2,000	dip			536	0	0	
DPA	42 D.W.	3,000	dip			487	0	0	1% injury (bottom fruit)
Stop Scald	70	1,800	crate spray			542	0	0	
Stop Scald	80	1,800	crate spray			520	0	1	
Stop Scald	70	2,700	crate spray			518	0	1	
DPA	42 D.W.	2,000	crate spray			425	0	0	18% injury (bottom fruit)
DPA	42 D.W.	3,000	crate spray			582	0	0	15% injury (bottom fruit)
Stop Scald	70	1,800	spray rollers			404	0	0	stain
Stop Scald	80	1,800	spray rollers			519	0	0	stain
Stop Scald	70	2,700	spray rollers			462	0	0	stain
DPA	42 D.W.	2,000	spray rollers			420	0	0	
DPA	42 D.W.	3,000	spray rollers			479	0	0	
Control (bin)						1,782	47	89	scald worse in lower half
Stop Scald (bin)	70	2,700	bin spray			1,925	0	2	scald worse at bottom
DPA (bin)	42 D.W.	2,000	bin spray			1,755	0	0	8% injury (on bottom)
1.5-mg. DPA oiled wrap			wrap			782	0	0	

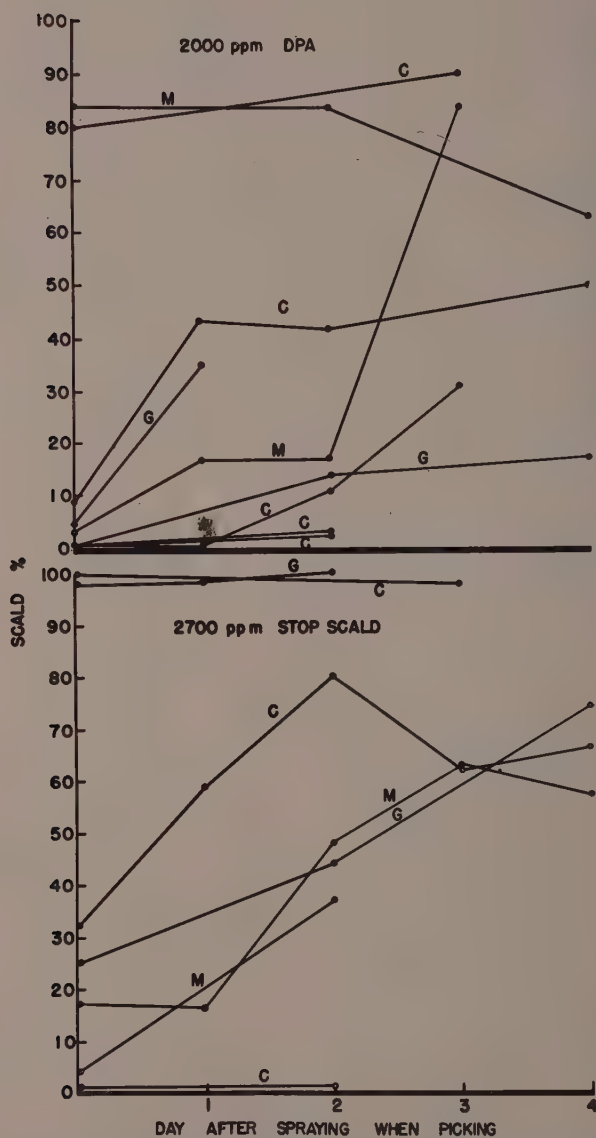


Figure 8. Effect of delay in picking after spraying tree with diphenylamine (DPA) and Stop Scald. G=R. I. Greening, M=McIntosh, C=Cortland.

terials. Fruit dipping gave perfect scald control with both materials. Spraying the fruit as it went over a roller sorter gave perfect control but there was some fruit stain with the Stop Scald—presumably from exposure to the sun. Spraying open crates of fruit gave essentially perfect control with both materials, but with DPA there was injury to 15 to 18 percent of the fruits because some of them lay in free liquid for a period of time. The scald in a 15-bushel capacity bulk bin was somewhat more severe than it was in the bushel boxes and also worse in the lower half than in the top half. Spraying the tops of these bins with approximately 1 quart per bushel of each material gave surprisingly good control of scald. However, with DPA there was again some injury to fruits on the bottom where they remained in the drainage liquid. Oiled wraps treated with 1.5 mg. of DPA gave perfect scald control.

McIntosh

The data in table 4 show that tree sprays with both materials gave relatively poor scald control except for the zero day picking of apples treated with DPA. The data also show that with tree sprays scald control was lessened as the interval between time of spraying and harvest increased (figure 8). The dip treatments and spraying the fruit as it went over a roller sorter gave about equal scald control. The DPA dip treatment caused injury of fruit at the bottom of the box because of drainage within the boxes. The crate sprays with Stop Scald gave poor control. DPA crate sprays caused injury, especially of the bottom fruit. DPA wraps gave only fair scald control in this experiment.

The scald was somewhat worse in bulk bins than in field crates. Bin sprays with DPA gave fairly good control but with Stop Scald did not. There was injury on the bottom fruit with DPA because of drainage to the bottom of the bin.

Cortland

Table 5 shows that tree sprays were not as effective in scald control as other methods. The tree spray data also indicate that for best results the fruit had to be picked the day of spraying (figure 8). All dip treatments gave excellent scald control. With crate sprays the control was not quite as good as with dipping. With the DPA crate-spray treatments there was 20 percent injury—all of it to the bottom fruits. Spraying on the roller sorter gave perfect scald control.

When bulk bins were immersed in Stop Scald emulsion the control was excellent. Bulk-bin sprays (flooding the top of the bin) did not give good control with Stop Scald but did with DPA. Bin sprays with DPA produced injury to the bottom fruit at both concentrations and throughout the bin at the concentration of 3000 p.p.m. Scald was slightly more severe in the bulk bins than in the crates.

It should be pointed out that with 2 of the 1800-p.p.m. Stop Scald treat-

Table 4. Scald control methods and results for McIntosh apples 1960-1961

Material	Formulation	Concentration	Method	Day picked after spraying	Trees	Fruit	Scald		Injury	Remarks
							Severe	Total		
Control.....	Percent.....	p.p.m.....	.....	0	8	Number 1,681	Percent 42.3	80.2	Percent 0	
Stop Scald.....	70	2,700	tree spray	0	4	567	3.2	16.8	0	
Stop Scald.....	70	2,700	tree spray	1	4	472	1.5	15.7	0	
Stop Scald.....	70	2,700	tree spray	2	4	626	8.9	48.3	0	
Stop Scald.....	70	2,700	tree spray	3	4	604	24.5	63.2	0	
Stop Scald.....	70	2,700	tree spray	4	4	524	8.9	56.8	0	
DPA.....	42 D.W.	2,000	tree spray	0	4	490	0.0	3.3	0	
DPA.....	42 D.W.	2,000	tree spray	1	4	628	3.5	16.7	0	
DPA.....	42 D.W.	2,000	tree spray	2	4	535	0.5	16.7	0	
DPA.....	42 D.W.	2,000	tree spray	3	4	615	6.6	83.7	0	
Stop Scald.....	70	1,800	dip	.....	.....	802	1.7	10.8	0	
Stop Scald.....	80	1,800	dip	.....	.....	503	0.0	5.7	0	
Stop Scald.....	70	2,700	dip	.....	.....	732	2.4	7.4	0	
DPA.....	42 D.W.	2,000	dip	.....	.....	517	0.0	0.0	5.4	bottom fruit injured
DPA.....	42 D.W.	3,000	dip	.....	.....	530	0.0	0.0	32.8	injury throughout
Stop Scald.....	70	1,800	crate spray	.....	.....	507	2.0	24.3	0	
Stop Scald.....	80	1,800	crate spray	.....	.....	565	5.1	46.2	0	
Stop Scald.....	70	2,700	crate spray	.....	.....	572	1.7	18.8	0	
DPA.....	42 D.W.	2,000	crate spray	.....	.....	544	0.0	0.7	3.7	bottom fruit injured
DPA.....	42 D.W.	3,000	crate spray	.....	.....	514	0.0	0.0	11.8	injury throughout
Stop Scald.....	70	1,800	spray rollers	.....	.....	538	0.6	4.1	0	
Stop Scald.....	80	1,800	spray rollers	.....	.....	553	0.0	6.3	0	
Stop Scald.....	70	2,700	spray rollers	.....	.....	542	0.4	7.6	0	
DPA.....	42 D.W.	2,000	spray rollers	.....	.....	529	0.0	6.8	0	
DPA.....	42 D.W.	3,000	spray rollers	.....	.....	529	0.0	0.0	0	
1.5-mg. oiled DPA wraps	.....	.....	wrap	.....	.....	614	1.3	11.8	0	
Control (bin).....	.....	.....	.....	.....	.....	1,895	71.3	92.3	0	
Stop Scald (bin).....	70	1,800	bin spray	.....	.....	2,030	7.1	49.9	0	
DPA (bin).....	42 D.W.	2,000	bin spray	.....	.....	1,807	3.9	7.8	5.0	bottom fruit injured

Note: rain between day 0 and day 1 on tree sprays; rain between days 2 and 3.

Table 5. Scald control methods and results for Cortland apples 1960-1961

Material	Formulation	Concentration	Method	Day picked after spraying	Trees	Fruit Number	Scald		Injury Percent	Remarks
							Severe Percent	Total Percent		
Control.....	Percent.....	p.p.m. ....	.....	0	8	1,525	40	88	0	
Stop Scald.....	70	2,700	tree spray	0	4	545	8	32	0	
Stop Scald.....	70	2,700	tree spray	1	4	556	14	38	0	
Stop Scald.....	70	2,700	tree spray	2	4	548	46	80	0	
Stop Scald.....	70	2,700	tree spray	3	4	487	24	62	0	
Stop Scald.....	70	2,700	tree spray	4	4	512	28	66	0	
DPA.....	42 D.W.	2,000	tree spray	0	4	459	1	9	0	
DPA.....	42 D.W.	2,000	tree spray	1	4	524	17	44	0	
DPA.....	42 D.W.	2,000	tree spray	2	4	556	20	42	0	
DPA.....	42 D.W.	2,000	tree spray	3	4	506	5	18	0	
DPA.....	42 D.W.	2,000	tree spray	4	4	511	32	50	0	
Stop Scald.....	70	1,800	dip	.....	.....	417	0	0	0	2% stain
Stop Scald.....	80	1,800	dip	.....	.....	474	0	1	0	2% stain
Stop Scald.....	70	2,700	dip	.....	.....	478	0	0	0	3% stain
Stop Scald.....	70	3,600	dip	.....	.....	477	0	0	0	3% stain
DPA.....	42 D.W.	2,000	dip	.....	.....	467	0	0	0	4% stain
DPA.....	42 D.W.	3,000	dip	.....	.....	448	0	0	0	
Stop Scald.....	70	1,800	crate spray	.....	.....	300	0	2	0	4% stain
Stop Scald.....	80	1,800	crate spray	.....	.....	488	0	1	0	3% stain
Stop Scald.....	70	2,700	crate spray	.....	.....	497	0	1	0	3% stain
Stop Scald.....	70	3,600	crate spray	.....	.....	612	0	1	0	4% stain
DPA.....	42 D.W.	2,000	crate spray	.....	.....	447	0	0	20	injury on bottom
DPA.....	42 D.W.	3,000	crate spray	.....	.....	449	0	0	20	injury on bottom
Stop Scald.....	70	1,800	spray rollers	.....	.....	577	0	0	13	heat injury—spot type
Stop Scald.....	80	1,800	spray rollers	.....	.....	495	0	0	0	1% stain
Stop Scald.....	70	2,700	spray rollers	.....	.....	334	0	0	0	1% stain
Stop Scald.....	70	3,600	spray rollers	.....	.....	616	0	0	0	6% stain
DPA.....	42 D.W.	2,000	spray rollers	.....	.....	419	0	0	0	
DPA.....	42 D.W.	3,000	spray rollers	.....	.....	435	0	0	0	
Control (bins).....	.....	.....	.....	.....	.....	1,920	56	94	0	
Stop Scald (bins).....	70	1,600	bin immersion	.....	.....	2,940	0	0.5	23	heat injury—spot type
Stop Scald (bins).....	70	1,800	bin spray	.....	.....	1,828	1	34	0	
DPA (bins).....	42 D.W.	2,000	bin spray	.....	.....	1,786	0	0	7	injury on bottom
DPA (bins).....	42 D.W.	3,000	bin spray	.....	.....	1,745	0	0	36	injury throughout

ments there was some injury. This was the first injury seen with such a relatively low concentration of this material. However, these particular apples had been sitting in the sun for several hours before treatment, and it is possible that high fruit temperatures caused the injury. It appeared as small black spots on the fruit.

Rome Beauty

The results with this variety are shown in table 6. The fruit treated with tree sprays was harvested on the day of treatment only. Tree sprays with both materials showed good scald control but it should be noted that even on untreated fruit the scald was not severe. In fact all methods of applications with both materials were unusually effective in scald control. However, it should be noted that DPA injury was a serious factor. There were two types of injury: one, a true "burn", is classified under "injury" in table 6; the other is classified as "circular spots". Untreated apples showed 2 percent of this latter trouble, which had never been seen before, but DPA seemed to greatly increase it. It resembled superficial bitter pit. Different formulations of DPA from various manufacturers showed no differences in control of scald. Unfortunately, concentrations lower than 2000 p.p.m. were not studied in this year's work with Rome Beauty to evaluate this injury factor. Stop Scald treatments did not produce any injury. Oiled paper wraps did not control scald.

Summary of DPA and Stop Scald results

The detailed data for 1960 have already been presented. Table 7 presents a summary of the DPA results and table 8 a summary of the Stop Scald results for all varieties and all years. This type of summary presented in terms of percentage control of scald should give an over-all picture of the results obtained with these two materials. Only experiments in which there was at least 70 percent total scald on the untreated apples were used so that the expression "percentage control" would have validity.

Table 7 shows that oiled wraps, the present method of scald control, was the poorest method of all those tested, but that wraps containing 1.5 mg. of DPA gave satisfactory scald control. Both plain and oiled DPA wraps were used in these trials but they are summarized together; the latter gave slightly better control than the former. Dipping apples in DPA was the best scald control method and spraying on the roller sorter was next. Spraying crates should be discounted because it resulted in too much fruit injury. Tree sprays gave the poorest results of all the DPA methods. Figure 8 shows the effect of delay in harvesting after trees were sprayed with DPA and Stop Scald. In general, control diminished as the time interval after spraying increased. This emphasizes the fact that if tree sprays are used, the fruits should be harvested within 36 hours after spraying. Table 8 shows that all methods of Stop Scald application gave better results than oiled paper wraps; with this substance, too, dipping was the best method and tree sprays the poorest.

Table 6. Scald control methods and results for Rome Beauty apples 1960-1961

Material	Formulation	Concentration	Method	Day picked after spraying	Trees	Fruit	Scald		Injury	Circular spots	Remarks
							Severe	Total			
	Percent	p.p.m.				Number	Percent	Percent	Percent		
Untreated.....	42 D.W.	2,000	tree spray	0	4	389	6	80	0	2	Mfr. A
DPA.....	42 D.W.	2,000	dip	0	4	348	0	1	0	20	Mfr. A
DPA.....	42 D.W.	2,000	dip	.....	.....	335	0	0	80	23	Mfr. B
DPA.....	25 D.W.	2,000	dip	.....	.....	254	0	0	16	39	Mfr. C
DPA.....	84 D.W.	2,000	dip	.....	.....	134	0	1	54	27	Mfr. B
DPA.....	42 D.W.	2,000	spray rollers	.....	.....	236	0	0	10	24	Mfr. A
DPA.....	42 D.W.	2,000	spray crates	.....	.....	374	0	0	2	18	Mfr. A
Stop Scald.....	70	2,700	tree spray	.....	.....	400	0	1	32	36	Mfr. A
Stop Scald.....	70	2,700	dip	0	4	386	0	2	0	6	
Stop Scald.....	70	2,700	spray rollers	.....	.....	375	0	0	0	4	
Stop Scald.....	70	2,700	spray crates	.....	.....	328	0	0	0	1	
Oiled wraps.....	.....	.....	wraps	.....	.....	369	0	88	0	0	

Table 7. Grand summary of average scald control with diphenylamine*
(Expressed as percentage control of scald †)

Variety	Oiled wraps			1.5-oz. DPA wraps			1000-p.p.m. DPA dip			2000-p.p.m. DPA dip			1000-p.p.m. DPA tree spray†		
	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol
	Number	Years	%	Number	Years	%	Number	Years	%	Number	Years	%	Number	Years	%
Wealthy.....	..	..	..	2	1	80	2	2	93	2	2	94	3	1	67
R. I. Greening.....	4	4	27	12	6	89	5	5	99	5	2	100	3	3	67
McIntosh.....	2	2	47	4	3	82	8	5	99	3	2	100	4	3	61
Cortland.....	4	3	78	10	4	94	5	5	97	4	4	96	2	2	63
Rome Beauty.....	2	2	0	3	2	89	1	1	85	1	1	100	1	1	58
Baldwin.....	2	2	66	2	1	98	5	5	96	4	4	96	..	..	..
Wagner.....	1	1	0	..	..	..	2	2	77	2	2	88	..	..	..
Delicious.....	..	..	..	..	..	..	3	1	100	1	1	100	..	..	..
Arkansas.....	..	..	..	1	1	96	1	1	100	..	..	..	..	..	..
Total tests.....	15	..	43	34	..	89	32	..	95	25	..	97	10	..	63
Average control.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Variety	2000-p.p.m. DPA tree spray†			1000-p.p.m. DPA spray rollers			2000-p.p.m. DPA spray rollers			1000-p.p.m. DPA crate spray			2000-p.p.m. DPA crate spray		
	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol
	Number	Years	%	Number	Years	%	Number	Years	%	Number	Years	%	Number	Years	%
Wealthy.....	3	3	52	..	..	..	2	2	87	1	1	24	1	1	62
R. I. Greening.....	6	6	84	2	2	100	3	3	98	1	1	100	2	2	100
McIntosh.....	3	2	49	2	2	97	2	2	79	..	..	..	1	1	99
Cortland.....	3	3	79	2	2	78	5	4	96	1	1	100	1	1	100
Rome Beauty.....	3	3	79	..	..	..	1	1	99	1	1	100	2	2	99
Baldwin.....	2	2	97	..	..	..	..	..	..	1	1	100	1	1	100
Wagner.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Delicious.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Arkansas.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total tests.....	30	..	78	6	..	92	13	..	93	5	..	85	8	..	95
Average control.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

* Apples from 1 to 7 locations within New York.

† Using experiments with at least 70% scald on untreated apples.

‡ Day 0 only.

Table 8. Grand summary of average scald control with Stop Scald (S.S.) *
(Expressed as percentage control of scald †)

Variety	Oiled wraps				900- or 1000-p.p.m. S.S. dip				1800- or 2000-p.p.m. S.S. dip				2700-p.p.m. S.S. dip				1800- or 2000-p.p.m. S.S. tree spray†				
	Tests		Con- trol		Tests		Con- trol		Tests		Con- trol		Tests		Con- trol		Tests		Con- trol		
	Number	Years	%	Number	Years	%	Number	%	Number	Years	%	Number	%	Number	Years	%	Number	Years	%	Number	%
Wealthy.....	4	1	90	1	1	90	2	94	2	2	94	1	97	2	1	2	1	1	2	1	2
R. I. Greening.....	4	5	57	4	4	76	4	74	4	4	74	1	100	1	1	1	1	1	1	0	10
Melrose.....	2	2	47	1	1	32	7	91	7	1	91	2	88	1	1	1	1	1	1	1	10
Cortland.....	4	3	78	8	5	74	8	76	8	5	76	2	33	2	2	2	2	2	2	49	2
Rome Beauty.....	1	1	0	1	1	99	1	100	1	1	100	1	100	2	1	1	2	1	1	15	2
Baldwin.....	2	2	66	1	1	99	3	100	1	1	100	1	100	2	1	1	2	1	1	70	2
Delicious.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total tests.....	14	..	46	16	..	74	25	86	25	..	86	7	81	7	..	81	10	..	..	..	34
Average control.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Variety	2700-p.p.m. S.S. tree spray†				1800- or 2000-p.p.m. S.S. spray rollers				2700-p.p.m. S.S. spray rollers				1800-p.p.m. S.S. spray on crates								
	Tests		Con- trol		Tests		Con- trol		Tests		Con- trol		Tests		Con- trol		Tests		Con- trol		
	Number	Years	%	Number	Years	%	Number	%	Number	Years	%	Number	%	Number	Years	%	Number	Years	%	Number	%
Wealthy.....	1	1	42	3	2	84	1	75	1	1	75	1	25	1	1	25	1	1	25	1	25
R. I. Greening.....	1	1	74	2	2	53	1	100	1	1	100	1	68	1	1	68	1	1	68	1	68
Melrose.....	2	1	87	2	2	51	1	89	1	1	89	1	56	1	1	56	1	1	56	1	56
Cortland.....	2	1	49	2	2	..	1	100	1	1	100	1	98	1	1	98	1	1	98	1	98
Rome Beauty.....	1	1	97	..	..	..	..	..	1	1	100	..	..	..	..	..	..	..	..	..	..
Baldwin.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Delicious.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total tests.....	7	..	76	6	..	63	5	93	5	..	93	4	..	4	..	..	4	..	..	..	69
Average control.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

* Apples from 1 or 2 locations within New York

† Using experiments with at least 70% scald on untreated apples.

‡ Day 0 only.

Presentation of average figures can be misleading unless the same materials were used at the same concentrations on every variety each year. Since this was not always done, the results are presented in another table (9) which includes the results for 1959 only. This was the worst scald year in the author's experience, presenting a severe test for all materials. Table 9 shows that DPA at equivalent concentrations was better than Stop Scald and that dipping was the best method of application, with spraying on the roller sorter next.

Effect of DPA and Stop Scald on ripening rate

An attempt was made to learn whether these scald-inhibiting chemicals had an effect on the ripening rate of apples in storage.

Figure 9 shows the effect of a 2000-p.p.m. dip treatment with 42 percent D. W. diphenylamine on the respiration rate of McIntosh apples at 4 different picking dates. For apples of the first picking (very immature fruit), the treatment delayed the start of the normal climacteric rise by at least 4 days. Later pickings showed no clear-cut effect of the treatment.

No other data on respiration rate are presented since they tend to confirm the results in figure 9. In 1956, Duchess apples were treated with 500- and 1000-p.p.m. dip treatments of DPA just as the climacteric rise started. Both concentrations retarded the climacteric rise slightly. The higher concentration had a greater effect than the lower one. In 1958 and again in 1960, Cortland apples were treated with 1000 and 2000 p.p.m. of DPA as a fruit dip shortly after the climacteric rise had begun. The treatment had no effect on respiration rate. In 1960, very immature McIntosh apples were treated on September 14 with a 2000-p.p.m. DPA dip. Untreated and treated samples were removed from air storage at 32° F. at 8-day intervals for 80 days. At each removal date the respiration rates were measured at 70° F. For the first 3 removal dates there was a slight reduction in the respiration rate of the DPA-treated samples. After that time there were no differences in respiration rate. In 1960, Wagener apples that had been treated at harvest time with 1000 and 2000 p.p.m. of DPA as a dip were removed from storage on December 28. Respiration was measured at 70° F. During the 8-day period there were no marked differences in respiration. These results tend to show that DPA treatments have no marked effect on respiration except on very preclimacteric fruit, where there is a reduction in rate. This observation confirms the findings of Yatsu (130).

Respiration studies of the effect of Stop Scald treatments on fruit respiration rate were made only during 1960. In one experiment with Cortland on very immature fruit there was no effect of 1800 p.p.m. of Stop Scald on respiration at 70° F. There was a slight stimulation in rate with 2700 p.p.m. of Stop Scald in the preclimacteric phase. Samples of Cortland apples that had been treated with 1800 p.p.m. of Stop Scald at harvest time were removed from air storage at 32° F. and CA storage at 38° F. These apples were held at 70° F. in air after removals in January and March. There were no marked effects of the Stop Scald treatment on respiration. Slightly pre-

Table 9. Summary of 1959 average scald control with DPA and Stop Scald (S.S.) °
(Expressed as percentage control of scald†)

Variety	1.5-mg. DPA wraps			2000-p.p.m. DPA dip			2000-p.p.m. DPA tree spray†			2000-p.p.m. DPA spray rollers			2000-p.p.m. S.S. dip			2000-p.p.m. S.S. tree spray†			2000-p.p.m. S.S. spray rollers		
	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol	Tests		Con- trol
	No.	%		No.	%		No.	%		No.	%		No.	%		No.	%		No.	%	
Wenthyr.....	3	80	..	1	99	..	1	44	1	99	..	..	2	36	..	2	0	2	2	87	..
R. I. Greening.....	3	47	..	..	..	..	1	13	1	93	..	..	1	..	..	1	9	1	1	4	..
Melrose.....	..	..	..	..	..	..	2	44	1	58	..	..	..	..	..	2	29	2	1	8	..
Cortland.....	..	..	..	..	..	..	2	58	..	82	..	..	..	..	..	2	15	1	1	40	..
Rome Beauty.....	..	..	..	2	98	..	1	96	..	..	..	..	..	..	..	1	52	..	..	..	..
Baldwin.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total tests.....	6	..	64	3	..	99	8	..	4	..	83	2	..	36	..	9	..	17	5	..	45
Average control.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

* Apples from 1 or 2 locations within New York.

† Using experiments with at least 70% scald.

‡ Day 0 only.

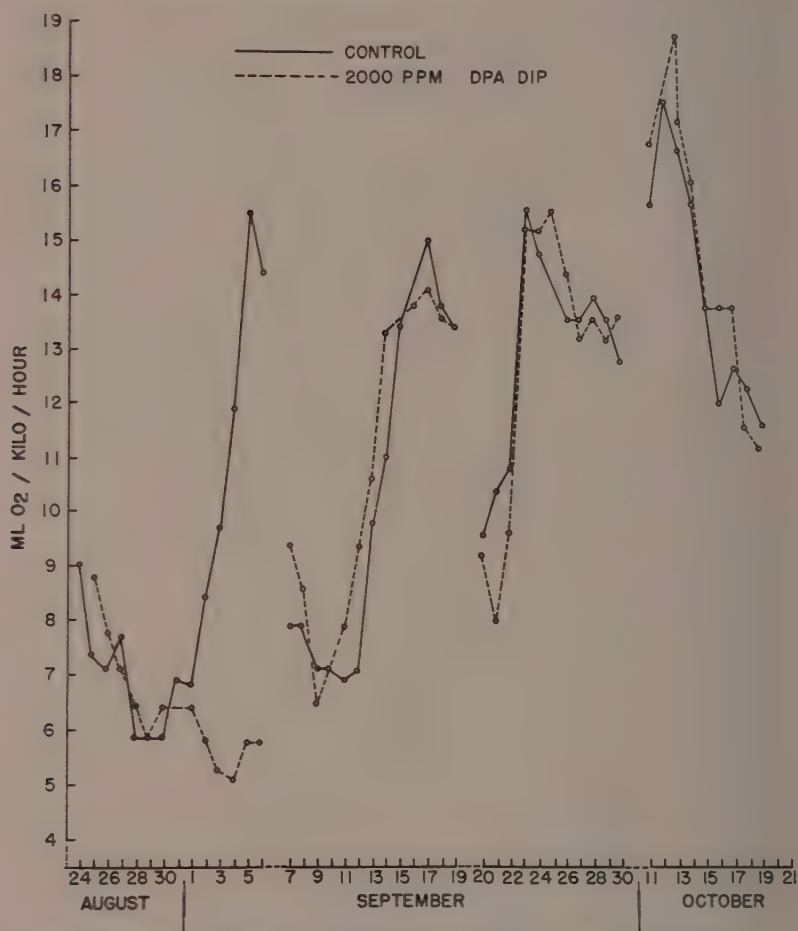


Figure 9. Effect of 2000-p.p.m. DPA dip on respiration at 70° F. of McIntosh apples picked at different dates in 1960.

climacteric Baldwin apples were removed from air storage at 32° F. December 19, 1960, and were treated with 2700 p.p.m. of Stop Scald as a dip. Respiration measurements made at 70° F. in air showed a slightly depressed respiration rate with the Stop Scald treatment.

Pressure-test readings were made on apples immediately after removal from storage. The results appear in table 10. The results for Stop Scald cover only 1 year. The average results show no significant effect of these scald-controlling chemicals on fruit firmness.

Table 10. Effect of diphenylamine and Stop Scald on fruit firmness after storage
(Expressed as pounds firmer than untreated apples)

Variety	Diphenylamine						Stop Scauld								
	500 p.p.m.			1000 p.p.m.			2000 p.p.m.			1800 p.p.m.			2700 p.p.m.		
	Years	Firm- ness		Years	Firm- ness		Years	Firm- ness		Years	Firm- ness		Years	Firm- ness	
		Number	Lbs. ±		Number	Lbs. ±		Number	Lbs. ±		Number	Lbs. ±		Number	Lbs. ±
Wealthy.....	..	2	0	2	4	+1.6	2	3	+0.6	..	..	..	..	..	..
R. I. Greening.....	2	2	-0.2	..	9	-0.2	2	8	+0.6	..	..	..	..	..	..
McIntosh.....	..	..	..	4	30	+0.3	2	6	+0.6	..	..	..	..	..	..
Cortland.....	2	3	+0.2	..	8	+0.2	5	14	+0.4	1	11	0	1	4	+0.7
Delicious.....	..	..	..	1	1	-0.4	..	..	..	..	..	..	..	..	..
Baldwin.....	..	..	..	2	2	-0.5	1	1	-0.4	..	..	..	..	..	..
Rome Beauty.....	..	..	..	2	3	-0.1	2	6	-0.1	1	3	-0.2	1	1	-0.2
Total tests.....	7				57			38			17			7	
Average ± firmness..			+0.03			+0.23			+0.11			+0.10			+0.6

Other inhibitors

Since the author's last publication on scald (110) other chemicals have been studied in regard to scald control. Table 11 gives the results. Some of the materials related to diphenylamine gave slight to excellent control although the number of tests was not large. None of the other materials showed any practical usefulness.

Table 11. Other chemicals studied in relation to scald control

Material	Maximum conc. used	Tests	Control relative to 1000-p.p.m. DPA dip	Remarks
	p.p.m.	Number		
Acridine.....	1,000	2	poor	
Acridone.....	1,000	2	fair	
Adenosine tri phosphate.....	1,000	1	none	
9-amino acridine hydrochloride.....	1,000	1	none	
Ascorbic acid.....	4,000	3	poor	
Beta-carotene.....	1,000	1	none	injury
Butylated hydroxyanisole.....	2,000	3	poor	injury
Diphenylamine hydrochloride.....	2,000	8	excellent	not water soluble
Diphenyl succinate.....	2,000	1	fair	
Ephedrine sulfate.....	1,000	1	none	
Gallic acid.....	4,000	3	none	
Gibberellic acid (potassium salt).....	250	2	none	
N-isopropyl N'phenyl-p-phenylene diamene.....	2,000	1	good	injury, black stain
Meta-hydroxy-diphenylamine.....	1,000	1	fair	
Para-amino-diphenyl.....	2,000	1	fair	
Para-amino diphenylamine.....	1,000	1	fair	injury
Para-hydroxy diphenylamine.....	1,000	2	good	
Phenothiazine.....	2,000	7	poor	
Piperazine.....	2,000	4	poor	
Phloroglucinol.....	2,000	2	none	
Phenergan hydrochloride.....	1,000	1	none	
Quercetin.....	1,000	1	none	injury
Resorcinol.....	2,000	2	none	
Syn-di-methyl diphenyl urea.....	10,000	3	poor	injury
Tannic acid.....	4,000	3	poor	
Thorazine hydrochloride.....	1,000	1	none	

Storage Temperature

The effect of storage temperature on scald is presented in table 12 for 4 varieties. The apples from each temperature comparison were examined for scald on the same date in any given year. Hence, Tindale's criticism (122) was not met. In 4 out of 9 years, the scald on McIntosh was less at 38° than at 32° F. On R. I. Greening the scald was less at lower storage temperatures than at higher in 3 out of 6 years. In 7 out of 9 years, Cortland apples sustained less scald at 38° F. than at 32° F. Fewer data are available for Wealthy, but they show that in the two years studied the scald was worse at 32° than at 38° F.

Table 12. Effect of storage temperature on scald

Year	Temp. (° F.)	Scald		Year	Temp. (° F.)	Scald		Year	Temp. (° F.)	Scald	
		Severe (%)	Total (%)			Severe (%)	Total (%)			Severe (%)	Total (%)
Wealthy											
1956.....	38	2	28	1949.....	38	..	100	1949.....	39	12	72
1956.....	32	82	99	1949.....	32	..	64	1949.....	33	4	31
1960.....	38	7	15	1950.....	38	..	25	1953.....	38	..	14
1960.....	36	10	31	1950.....	32	..	0	1953.....	32	..	91
1960.....	32	75	87	1951.....	38	..	100	1954.....	38	..	81
1960.....	30	46	64	1951.....	32	..	81	1954.....	32	..	100
R. I. Greening											
1955.....	38	100	100	1953.....	38	..	12	1955.....	38	45	68
1955.....	32	85	97	1953.....	32	..	100	1955.....	32	90	100
1956.....	38	59	100	1954.....	38	..	100	1955.....	30	83	91
1956.....	32	81	96	1954.....	32	..	100	1956.....	38	33	61
1956.....	30	6	15*	1955.....	32	..	100	1956.....	32	40	72
1957.....	38	57	93	1955.....	31	..	88	1956.....	30	1	7
1957.....	32	36	72	1956.....	38	..	18	1957.....	38	3	36
1957.....	38 one month, then 32	66	95	1956.....	32	..	56	1957.....	33	6	46
1957.....	30	9	29*	1956.....	30	..	56	1958.....	38	..	72
1957.....	38	91	99	1958.....	38	..	61	1958.....	32	..	70
1959.....	32	69	96	1958.....	32	..	100	1958.....	30	..	48
1959.....	30	17	48	1958.....	30	..	46	1959.....	38	70	94
1959.....	38	53	86	1959.....	38	..	100	1959.....	36	94	99
1960.....	36	35	66	1959.....	36	..	100	1959.....	32	100	100
1960.....	32	17	26*	1959.....	32	..	86	1959.....	30	100	100
1960.....	30	0		1960.....	38	..	36	1960.....	38	19	85
				1960.....	36	..	30	1960.....	36	71	96
				1960.....	32	..	85	1960.....	32	99	100
				1960.....	30	..	90	1960.....	30	84	99

* Brown heart and brown core severe.

Storage Atmosphere

The effects of various carbon dioxide and oxygen levels on scald as determined by tests with 2-bushel lots of apples, are presented in table 13. Some of this work was conducted in cooperation with Dr. G. D. Blanpied. Studies with McIntosh showed clearly that when some carbon dioxide was present low oxygen levels resulted in less scald than high oxygen levels. In 1959 the effect of oxygen level in conjunction with different carbon dioxide levels was studied. Low oxygen levels combined with low carbon dioxide reduced scald somewhat. Relatively high carbon dioxide levels alone (oxygen 21 percent) did not reduce scald. There may have been an additive effect between the two gas levels, since minimum scald on McIntosh seemed to be obtained with relatively high carbon dioxide and low oxygen. The results for Rome Beauty and Delicious show that low oxygen with relatively high carbon dioxide reduced the scald except for 2 years with Delicious. The CA storage seemed to reduce the scald on Cortland at 32° F. and to increase it at 38° F.

Table 13. Effect of carbon dioxide and oxygen levels in storage on scald

Year	Temp. (° F.)	CO ₂ (%)	O ₂ (%)	Total scald (%)	Year	Temp. (° F.)	CO ₂ (%)	O ₂ (%)	Total scald (%)
McIntosh									
1949.....	32	air	air	64	1958.....	32	air	air	98
1949.....	38	air	air	100	1958.....	38	air	air	88
1949.....	38	5	3	20	1958.....	38	2	3	0
1950.....	32	air	air	25	1958.....	38	5	3	37
1950.....	38	air	air	0	1959.....	38	air	air	100
1950.....	38	5	3	0	1959.....	38	6	21	100
1951.....	32	air	air	81	1959.....	38	8	21	100
1951.....	32	5	16	11	1959.....	38	8	6	87
1951.....	38	air	air	0	1959.....	38	5	5	24
1951.....	38	5	3	0	1959.....	38	8	3	0
1952.....	34	air	air	100	1959.....	38	5	4	13
1952.....	38	5	3	1	1959.....	38	0.5	5	100
1953.....	32	air	air	100	1959.....	38	0.5	4	59
1953.....	38	5	3	12	1959.....	36	air	air	100
1954.....	32	air	air	100	1959.....	36	8	21	100
1954.....	38	air	air	100	1959.....	36	5	21	100
1954.....	38	5	3	2	1959.....	36	8	6	29
1955.....	32	air	air	100	1959.....	36	6	5	81
1955.....	38	5	3	7	1959.....	36	8	4	2
1955.....	38	10	3	0	1959.....	36	5	4	0
1956.....	32	air	air	71	1959.....	36	0.5	5	98
1956.....	38	5	3	0	1959.....	36	0.4	4	76
1956.....	38	7	14	84	1959.....	32	air	air	86
1957.....	32	air	air	100	1959.....	32	8	21	30
1957.....	38	5	3	65	1959.....	32	5	22	77
					1959.....	32	8	5	4
					1959.....	32	5	5	6
					1959.....	32	8	4	1
					1959.....	32	5	4	12
					1959.....	32	0.5	5	70
					1959.....	32	0.4	4	79

Table 13 — Continued

Year	Temp. (° F.)	CO ₂ (%)	O ₂ (%)	Total scald (%)	Year	Temp. (° F.)	CO ₂ (%)	O ₂ (%)	Total scald (%)
Cortland									
1948.....	35	air	air	68	1955.....	32	air	air	100
1948.....	35	5	4	84	1955.....	32	2	3	5
1948.....	38	air	air	9	1955.....	32	5	3	3
1948.....	38	5	3	84	1956.....	32	air	air	32
1949.....	33	air	air	31	1956.....	32	5	3	0
1949.....	39	air	air	72	1957.....	32	air	air	100
1949.....	39	5	3	100	1957.....	32	2	3	2
1953.....	32	air	air	91	1957.....	32	5	3	3
1953.....	32	5	3	0	1958.....	32	air	air	70
1953.....	38	5	3	50	1958.....	32	2	3	100
1954.....	32	air	air	100	1958.....	32	5	3	84
1954.....	32	1	3	100	1958.....	38	5	3	100
1954.....	32	2	3	80					
1954.....	32	5	3	15					
Rome Beauty									
1951.....	38	air	air	28	1955.....	32	air	air	99
1951.....	38	5	3	0	1955.....	32	2	3	1
1952.....	34	air	air	100	1955.....	32	5	3	3
1952.....	34	5	3	0	1957.....	32	air	air	86
1952.....	34	10	3	0	1957.....	32	1	3	8
1954.....	32	air	air	100	1957.....	32	3	3	2
1954.....	32	5	3	0					
1954.....	32	10	3	0					
Delicious									
1952.....	32	air	air	74	1956.....	32	air	air	56
1952.....	32	2	3	89	1956.....	32	2	4	0
1952.....	32	5	3	0	1956.....	32	5	3	0
1953.....	32	air	air	9	1957.....	32	air	air	4
1953.....	32	2	3	4	1957.....	32	1	4	3
1953.....	32	5	3	0	1957.....	32	2	4	6
1954.....	32	air	air	40	1958.....	32	air	air	11
1954.....	32	2	3	0	1958.....	32	2	3	31
1954.....	32	5	3	0					
1955.....	32	air	air	68					
1955.....	32	2	3	1					
1955.....	32	5	3	2					
Stayman									
1953.....	32	air	air	80	1956.....	32	air	air	100
1953.....	32	5	3	0	1956.....	32	4	4	100
1955.....	32	air	air	100					
1955.....	32	5	3	10					
R. I. Greening									
1956.....	32	air	air	100	1957.....	32	air	air	100
1956.....	32	2	3	0	1957.....	32	2	3	2

Aeration in Storage

Small-scale studies using Cortland and R. I. Greening were conducted on the effect of air stagnation or movement on scald. One treatment involved holding in storage with other apples 2 box lots of apples in open field crates. The relative humidity in these rooms ranged between 90 and 95 percent. This treatment is referred to as "O" (open box) in table 14. In another

Table 14. Effect of aeration on scald

Year	Treatment*	Temperature (degrees F.)	No. of air changes/hour	Scald	
				Severe (%)	Total (%)
Cortland					
1951.....	O	38	..	..	5
1951.....	R	38	..	..	50
1953.....	O	32	..	..	81
1953.....	R	32	..	..	90
1953.....	O	38	..	..	22
1953.....	R	38	..	..	76
1954.....	O	33	..	..	41
1954.....	R	33	..	..	50
1954.....	A	33	8	..	32
1954.....	O	38	..	..	10
1954.....	R	38	..	..	38
1955.....	O	33	..	..	84
1955.....	R	33	..	..	100
1955.....	A	33	8	..	88
1955.....	O	38	..	..	62
1955.....	R	38	..	..	100
1956.....	O	33	..	..	2
1956.....	R	33	..	..	55
1956.....	A	33	8	..	1
1956.....	O	38	..	..	4
1956.....	R	38	..	..	87
1957.....	O	33	..	..	46
1957.....	R	33	..	..	58
1957.....	A	33	8	..	47
1957.....	O	38	..	..	36
1957.....	R	38	..	..	84
1958.....	O	33	..	..	34
1958.....	R	33	..	..	85
1958.....	A	33	8	..	36
1958.....	O	38	..	..	4
1958.....	R	38	..	..	22
R. I. Greening					
1959.....	O	32	..	69	96
1959.....	R	32	..	67	94
1959.....	A	32	75	45	95
1959.....	A	32	8	76	90
1959.....	A	32	1	79	100
1960.....	O	32	..	17	66
1960.....	R	32	..	79	99
1960.....	A	32	75	23	71
1960.....	A	32	40	40	80
1960.....	A	32	8	48	95

* O = open boxes; R = recirculation with 0.5% CO₂; A = aspiration.

treatment, duplicate 40-apple lots were placed in sealed 5-gallon glass jars. The air was recirculated around these apples with a mercury or mechanical "heart pump" at the rate of 2 cubic feet per hour. Sufficient outside air was introduced into the system continuously to maintain approximately 0.5 percent of carbon dioxide in each jar. The outside air was humidified by being bubbled through water. This treatment is referred to in table 14 as "R" (recirculation). In a third treatment, duplicate lots of 40 apples were placed in sealed 5-gallon jars and temperature-conditioned outside air was aspirated over the fruit. These treatments involved 1 through 8 air changes per hour, as indicated in table 14. Where high air rates were involved (40 and 75 air changes per hour), unduplicated lots of 10 to 40 apples were placed in a 4-foot-long piece of iron pipe (3" diameter) 1 layer deep. This treatment is referred to as "A" (aspiration) in table 14. In the aspiration ("A") treatments, the outside air was humidified by being bubbled through water.

Experiments of this type are supposed to test the effect of accumulating or removing natural fruit volatiles. These experiments do not exclude possible relative humidity effects. For example, in the "A" and "R" treatments the relative humidity around the fruits was 100 percent, as judged by the presence of free moisture. The relative humidity around the fruit in the open boxes was 90 to 95 percent.

Table 14 shows that in a 7-year experiment with Cortland apples, the scald ranged from slightly to considerably worse in the "R" treatment than in the "O" treatment in all years. In the 5 years when the "A" treatment was used, the "O" and "A" treatments showed less scald than the "R" treatments. In all 5 years, 8 air changes per hour gave results comparable with those for fruit in open boxes. It should be remembered, however, that the relative humidity was different in the two treatments.

In a 2-year test with R. I. Greening, the "R" treatment gave more scald in one year only. Very severe scald prevailed in 1959 — a year in which there were no differences. Eight air changes per hour did not result in less scald than was found in open boxes. In 1960–61, not even 75 air changes per hour resulted in less scald than was found in open boxes. However, within the aspiration treatments, increasing rates of air flow produced less severe scald.

Results with unsealed polyethylene box liners are not presented because they duplicate results previously reported (110). The liners usually, but not always, increased the scald. The relative humidity in unsealed liners tends to be 100 percent. The higher incidence of scald among the "R" and unsealed-liner treatments could be due to the high relative humidity or accumulated volatiles or both, or even to some unknown factor. The present study has not resolved this problem. The only situation where comparable humidities allow a scrutiny of the effect of volatile removal is in a comparison of the A and R treatments. This comparison suggests that removal

of volatiles may decrease scald slightly, yet it must be remembered that even 75 air changes per hour did not control scald.

Air Purification

Since the author's last publication on air purification (107), several more experiments have been conducted. Test lots of 2 bushels each of apples were placed in cold storage rooms with and without air purified by coconut shell carbon. The rooms were of 1500-box capacity. Air purification was accomplished with "4-plate units" through which the storage atmosphere was circulated with a blower.

Table 15 shows that air purification gave some scald reduction in some years but that it never gave satisfactory control when scald incidence was severe. It is therefore concluded that air purification was not a dependable means of scald control.

Table 15. Relation of scald control to air purification with activated carbon

Year	Treatment	Temperature (degrees F.)	Type of storage	Scald	
				Severe (%)	Total (%)
R. I. Greening					
1954.....	control	32	regular	32	100
1954.....	carbon	32	regular	2	29
1955.....	control	32	regular	65	97
1955.....	carbon	32	regular	33	56
1958.....	control	32	regular	36	72
1958.....	carbon	32	regular	31	75
Cortland					
1954.....	control	32	regular	1	6
1954.....	carbon	32	regular	0	0
1955.....	control	32	regular	90	100
1955.....	carbon	32	regular	95	97
1956.....	control	32	regular	40	72
1956.....	carbon	32	regular	0	1
1958.....	control	32	regular	..	70
1958.....	carbon	32	regular	..	35
McIntosh					
1958.....	control	32	regular	..	100
1958.....	carbon	32	regular	..	92
1958.....	control	38	CA	..	12
1958.....	carbon	38	CA	..	0
1959.....	control	38	CA	..	50
1959.....	carbon	38	CA	..	46

Mixed Varieties in Storage

If scald is caused by fruit volatiles, the question arises as to whether one lot of apples can influence the scald on another. This problem was studied in several ways. In one method, outside air, the temperature and relative humidity of which was conditioned, was passed over the apples at the rate of approximately 8 air changes per hour. There were two, 5-gallon, unduplicated jars, each containing 40 apples. In one jar was the "variety being tested" and in the other was the "variety supplying the 'scald vapors'". (See table 16 under method "A" [aspiration].) The vapors of the latter were passed over the variety being tested for scald. In the only variety combination tested with this procedure, the vapors of McIntosh apples did not increase the scald on Cortland apples. In another method, duplicate boxes of R. I. Greening and McIntosh apples were used. Both varieties were either stored alone in open boxes or boxes lined with unsealed 150-gauge polyethylene box liners ("L") or were mixed together. The results in table 16 show that in 2 out of 3 years, McIntosh increased the scald on Greenings

Table 16. Influence of one variety on another with regard to scald

Year	Variety tested	Variety supplying "scald vapors"	Method*	Temp. (° F.)	Scald	
					Severe (%)	Total (%)
1954.....	Cortland	.....	A	32	..	32
1954.....	Cortland	McIntosh	A	32	..	20
1955.....	Cortland	.....	A	33	..	88
1955.....	Cortland	McIntosh	A	33	..	94
1956.....	Cortland	.....	A	33	..	2
1956.....	Cortland	McIntosh	A	33	..	0
1957.....	Cortland	.....	A	33	..	47
1957.....	Cortland	McIntosh	A	33	..	64
1958.....	Cortland	.....	A	33	..	36
1958.....	Cortland	McIntosh	A	33	..	37
1958.....	Cortland	.....	L	33	..	68
1958.....	Cortland	McIntosh	L	33	..	49
1958.....	R. I. Greening	.....	O	33	..	72
1958.....	R. I. Greening	McIntosh	O	33	..	90
1958.....	R. I. Greening	.....	L	33	..	78
1958.....	R. I. Greening	McIntosh	L	33	..	97
1959.....	R. I. Greening	.....	O	33	..	91
1959.....	R. I. Greening	McIntosh	O	33	..	85
1959.....	R. I. Greening	.....	L	33	..	27
1959.....	R. I. Greening	McIntosh	L	33	..	83
1960.....	R. I. Greening	.....	O	32	17	66
1960.....	R. I. Greening	McIntosh	O	32	82	99
1960.....	R. I. Greening	.....	L	32	11	35
1960.....	R. I. Greening	McIntosh	L	32	15	40
1960.....	McIntosh	.....	O	32	28	58
1960.....	McIntosh	R. I. Greening	O	32	68	91
1960.....	McIntosh	.....	L	32	15	36
1960.....	McIntosh	R. I. Greening	L	32	19	55

* A = aspiration; O = open boxes; L = unsealed 150-gauge poly liner.

somewhat when stored with them, both in open boxes and in liners. In a 1-year test, Greenings increased the scald on McIntosh when stored with them in open boxes and in liners.

These results are not conclusive but they suggest that one variety in close proximity to another may increase the scald on the other, as Padfield (75) and Stoll (118) have reported. More work must be done on this subject before final conclusions can be made.

Discussion

While climate seems to play a part in susceptibility to scald, all the factors responsible for a "bad scald year" have not yet been defined.

Nutrition did not have a measurable effect on scald susceptibility except that high nitrogen somewhat lessened the susceptibility of Cortland trees. Early pickings put in ordinary cold storage consistently sustained more scald than later pickings. The reverse was true for McIntosh in CA storage. The reason for this is not known.

The intensity of scald on certain varieties can be predicted by storing the apples in unsealed polyethylene box liners for 6 weeks at 70° F. But since this method underestimates the scald, it is of no value for other varieties — Wealthy, for example. This evidence suggests that Tindale's idea (122) that scald is a cold-induced or aggravated trouble with certain varieties is correct.

Delays between harvesting and air storage had no consistent effect on scald. Occasionally the scald was worse with delay and at other times it was slightly reduced. For McIntosh apples, delay before CA storage consistently increased the scald. This observation is probably related to the effect of maturity mentioned previously.

The scald-induction period (when scald starts to form in storage) seemed to vary with the variety and the season. In a severe scald year, it started earlier than in a light scald year. The results emphasize that any scald-controlling treatment should be put on the apples at harvest time or within a week after the apples go into storage.

Dipping the fruit seemed to be the most effective means of controlling scald with either DPA or Stop Scald. This method gives the best fruit coverage. A concentration of 1000 to 2000 p.p.m. of DPA or 1800 to 2700 p.p.m. of Stop Scald seem to be preferred. The fruit does not have to be dried before being placed in storage but any free drainage should be emptied from the containers. This injury is more of a hazard with DPA than Stop Scald.

Spraying or flooding the fruit as it turned over a 2-foot section of roller sorter was the second-best method of application. This, like dipping, requires extra fruit handling.

Spraying crates or bulk bins of loose fruit with DPA at the rate of 1 quart per bushel of fruit gave surprisingly good control of scald for all varieties except Wealthy. However, there is danger of drainage liquid in the bottom of the container burning the fruit, especially when DPA is used. This method was not successful with Stop Scald.

In just one experiment good results were obtained when bulk bins of apples were immersed in Stop Scald. Again, free drainage liquid (especially from DPA) should be removed before the apples are stored.

Tree sprays gave the poorest scald control of any method employed. Inadequate coverage probably accounts for the unsatisfactory results. Sometimes control was excellent; on other occasions it was poor. Scald control lessened as the interval between spraying and picking increased. When this method is used, the apples should be picked the day they are sprayed. This method is the cheapest in terms of application cost, but it is expensive because of the tremendous waste of material. Results with a gun spray were better than with a "speed sprayer," presumably because of better coverage.

DPA on paper wraps usually gave satisfactory scald control but the results were not as good as with DPA dips. The suggested amount of DPA per 10" x 10" wrap is 1.5 milligrams. The results were better when the treated wraps were oiled paper rather than plain paper. DPA wraps were definitely better than plain oiled wraps.

Other methods of DPA application have been suggested. The material can be vaporized with steam and the apples treated in a tunnel containing DPA vapor plus steam (58). This method was tried for 2 years with several varieties but the results were not reported. In the first year insufficient residues of DPA were deposited on the apples. In the second year the apples developed steam burns in the tunnel. The method has considerable merit, partly because it uses such small quantities of the chemical, but the tunnel must be very carefully engineered. A method of DPA application has been developed in New Zealand that involves flooding the apples in crates with DPA in Octaro oil (20). The crates of apples must first be wet with water, then flooded with DPA emulsion, and then rinsed with water. The time required during the flooding operation depends greatly on the variety and the particular lot of fruit. The method seems cumbersome.

Fruit injury is a possibility with both DPA and Stop Scald. (See figures 10 and 11.) DPA injury occurred when free liquid remained around the fruit for some time. For example, when crates were sprayed, bottom fruits were often injured. When bulk bins were sprayed with 3000 p.p.m. of DPA, there was injury throughout the bin. With dipping, spraying on roller sorter, and tree spraying, injury from DPA at concentrations up to 2000 p.p.m. was unusual although it was occasionally seen on Baldwin and Rome Beauty. Concentrations of more than 1000 p.p.m. should not be used on these varieties. At the same concentration, Stop Scald was less injurious to apples than DPA. For example, even crate and bin sprays with 2700 p.p.m.

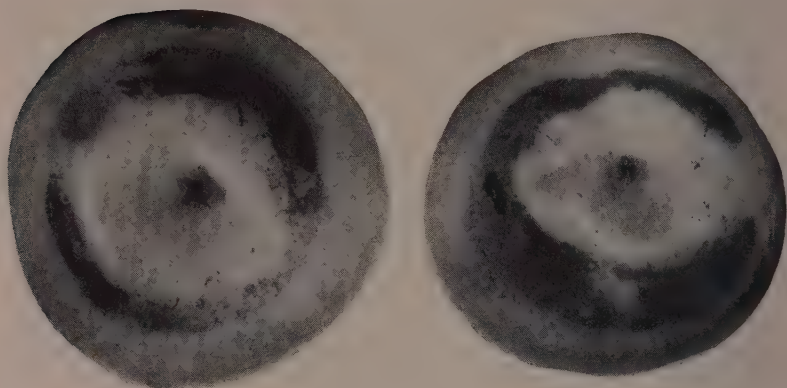


Figure 10. Diphenylamine injury on Cortland apples. These apples stood in drainage liquid in bottom of containers.

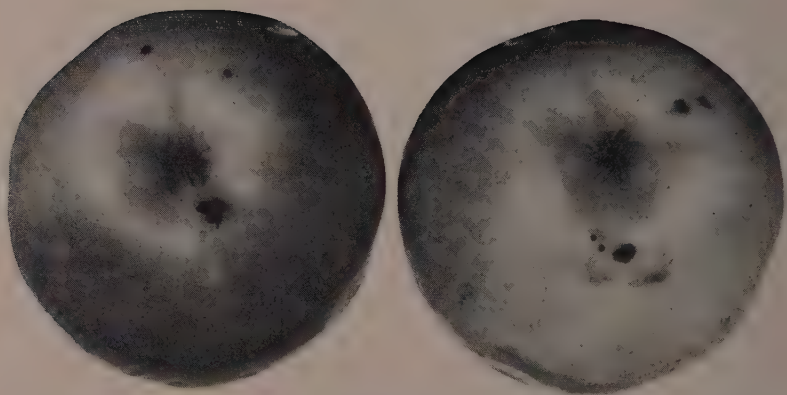


Figure 11. Stop Scald injury to Delicious apples. This occurred when apples were very warm when treated.

did not injure the bottom fruit. Spot injury was sometimes found on fruit treated with Stop Scald. This injury occurred when the fruit was treated, either on or off the tree, during unusually hot weather (90° to 100° F.). Stop Scald sometimes left on the fruit a small black stain that could be rubbed off. This stain was especially common when fruits were treated outdoors.

No ripening effects were noted from treatment with either DPA or Stop Scald. At harvest time, DPA tended to reduce the respiration rate of very immature apples but had no effect on fruits picked later. Reports state that Stop Scald has a yellowing effect on Granny Smith, a green variety (57). Yellowing was not noted in the present study but it is an effect that should be watched for.

Residues of DPA on treated apples were determined; however the results of these tests will be reported in a separate publication. In most years, 3 to 5 p.p.m. DPA residue on the fruit at harvest time was sufficient to give adequate scald control.

The effect of storage temperature on scald does not seem as clear cut as it once did (8). Some varieties scald worse in some years at 32° F. than they do at 38° F., which suggests that Tindale's estimation of scald as a low-temperature disorder has some merit (122). Yet in some years, certain varieties scalded less at 32° F.

For varieties like McIntosh, low-oxygen atmospheres inhibited scald. However, this did not mean that these varieties could not scald in CA storage. Accumulations of carbon dioxide plus low oxygen seemed to have an additive effect in reducing scald on McIntosh. CA storage often increased the scald at 38° F. and reduced it at 32° F. on other varieties, such as Cortland. A rapid oxygen drop to 3 percent resulted in less scald on most varieties.

Rapid air exchange over scald-susceptible apples did not control the scald. Any study that involves the relation of fruit volatiles to scald must separate the effects of relative humidity and volatiles. This was not done in this study. There is little direct proof here but there is some evidence that atmospheres saturated with water vapor increase scald. Either volatiles or relative humidity could have been the cause of variations in scald intensity in a number of the test situations, such as: the differences noted in the effects of varying rates of air flow on scald, the fact that scald was often worse in the bottom of the bulk bins of untreated fruit or that it was usually worse in unsealed box liners. Air purification with activated carbon had no real effect on relative humidity, yet it sometimes decreased scald. This would suggest an effect of fruit volatiles on scald. The data are very limited in this study but previous studies (51, 75, 105, and 118) have also indicated an influence of one lot of apples on another in inducing scald. This would suggest a volatile effect.

Summary

Hot, dry weather during the period 6 weeks before harvest increased the susceptibility of McIntosh apples to scald.

Orchard nutrition did not show any real effects on susceptibility to scald.

In regular cold storage, immature apples scald worse than mature apples. In CA storage, mature McIntosh apples scald worse than immature ones.

A rough prediction of scald intensity in any given year can be made by storing samples of apples in unsealed polyethylene box liners at 70° F. for 6 weeks immediately after harvest.

Delayed storage had no consistent effect on scald of apples in air storage. It increased the scald on McIntosh in CA storage.

Scald seems to start forming early in the storage period. Just when it begins depends upon the variety and the season.

Diphenylamine and Stop Scald were the most effective scald-inhibiting chemicals. The best method of application was as a dip. Spraying the fruit as it went over a roller sorter was the second most effective method. Spraying loose fruit in open crates or bulk bins was fairly effective with some varieties but not with others. Tree spraying was the least effective method of application. Oiled wraps treated with DPA (1.5 to 2.0 mg./wrap) were the best wrap treatment for the control of scald.

The effect of storage temperature depended upon the variety and, in some cases, the season.

Controlled-atmosphere storage reduced the scald on all varieties tested in most years except for Cortlands stored at 38° F.

Volatile removal by either air purification or aeration were not effective means of scald control.

Limited data suggested that one variety stored in the same box with another variety could increase the scald on one or both varieties.

In a 1-year study, scald tended to be slightly worse in bulk bins than in standard field boxes.

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